Per (sec. 15)

SCIENCE

2 June 1961

Vol. 133, No. 3466

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

6 JUN 1 - 1961
Cont

450 866

LEITZ EXCLUSIVE: *the only quality microscope that combines these important features...*

BINOCULAR MEDICAL AND LABORATORY MICROSCOPE SM. Equipped with inclined binocular body; mechanical stage; two-lens condenser with swing-out upper element and iris diaphragm; quadruple nosepiece; mirror and fork. Optical outfit with achromats 3.5x, 10x, and 45x and 100x oil immersion with spring-loaded mounts plus 10x eyepieces.

MONOCULAR MEDICAL AND LABORATORY MICROSCOPE SM. Same as above, but equipped with inclined monocular tube. If desired, monocular microscope can be converted to a binocular unit in a simple one-step operation.

LEITZ TECHNICAL SERVICE is unique in the United States, providing one of the most extensive service and repair facilities in the field of scientific instruments.

1. ***Single-knob focusing*** combines coarse and fine focusing for faster, more convenient operation...saves time... simplifies your microscope studies...lets you work in greater comfort and ease.
2. ***The world's finest optics***...high precision construction ...the most exacting operation – all in a moderately priced instrument.
3. ***Accepts all standard slide sizes.*** Mechanical stage accepts both 3" x 1" and 3" x 2" slides.
4. ***Retractable spring-load mounts*** on high-powered objectives provide positive protection against damage to slide or front lens.
5. ***Anti-reflection coating*** on tubes and optics throughout.
6. ***Extra-wide objective magnification range 45-1250x.***
7. ***Monocular or binocular body rotatable 360°*** with one-step locking at any point.
8. ***Variety of mechanical stages*** available.
9. ***Selection of attachable illuminators,*** interchangeable with mirror.
10. ***Wide-field or high-eyepoint eyepieces*** (for wearers of glasses) available at slight extra cost.
11. ***Contour-fitted carrying case*** protects microscope.

GET ALL THE FACTS...WRITE FOR LITERATURE... for full information on all the important new features and conveniences built into the latest SM microscope.

FILL OUT COUPON...MAIL TODAY!

E. LEITZ, INC. Dept: SC-62
468 Park Avenue South, New York 16, New York
Gentlemen: Please send me complete information on the:
☐ Model SM microscope.
☐ Kindly have representative ☐ phone or ☐ write me for appointment to demonstrate SM microscope at no obligation to me.

Name_____
Address_____
City_____ Zone_____ State_____
Telephone_____

37761

Leitz

E. LEITZ, INC., 468 PARK AVENUE SOUTH, NEW YORK 16, N. Y.
Distributors of the world-famous products of Ernst Leitz G. m. b. H., Wetzlar, Germany—Ernst Leitz Canada Ltd.
LEICA CAMERAS · LENSES · PROJECTORS · MICROSCOPES · BINOCULARS

An Information-Crammed Text Providing a Beautifully Organized Picture of Functional Relationships

A Saunders Book

NEW (2nd) EDITION

COMPARATIVE ANIMAL PHYSIOLOGY

C. Ladd Prosser, Ph.D.
Professor of Physiology
University of Illinois

and

Frank A. Brown, Jr., Ph.D.
Professor of Biology
Northwestern University

Here is a brand new *Second Edition* of a famous work on animal physiology. In its completely rewritten pages, you'll find a wealth of vital information on a myriad of animal body functions —from elementary ionic regulation to complex sequential behavior patterns.

Arranged on a functional rather than a phylogenetic basis, the text illuminates organ operation and activity in organisms ranging from simple one-celled types to complicated mammals. Detailed description and discussion is devoted to important physiological concepts such as: Feeding and Digestion; Nitrogen Excretion; Temperature; Chemoreception; Muscle and Electric Organs; Endocrine Mechanisms; etc. *See Contents to the right.*

The opening two-thirds of the book deals with environment-organism interaction and the remainder with effector and integrative systems. In discussing physiologic development and mechanisms, the influence of phylogeny, speciation, ecology, and variation are all carefully considered.

Evolutionary relationships of various kinds of animals are clearly delineated, including fascinating discussions on how particular characteristics serve their functional and environmental requirements.

Since this book presents a scholarly study of the physiological and biochemical characteristics of animals, it is ideally suited to courses in Comparative Physiology at the advanced undergraduate and early graduate level. The vast range and depth of information in this classic makes it a significant and extremely useful reference for anyone active in the biological sciences.

CONTENTS

Introduction—Water: Osmotic Balance—Inorganic Ions—Nutrition—Feeding and Digestion—Nitrogen Excretion—Oxygen: Respiration and Metabolism—Respiratory Functions of Body Fluids—Temperature—Mechanoreception, Equilibrium Reception, and Phonoreception—Chemoreception—Photoreception—Circulation of Body Fluids—Muscle and Electric Organs—Amoeboid Movement—Cilia—Trichocysts and Nematocysts—Bioluminescence—Chromatophores and Color Change—Endocrine Mechanisms—Nervous Systems.

In the chapters listed above you'll find vivid discussions on fascinating topics such as: variations of external respiration; carbon dioxide transport; supercooling in winter-hardened insects; acclimation to prolonged exposure to cold; equilibrium reception; echo-orientation; light sensitivity without eyes; the vertebrate camera eye; time relations of muscle; theories of amoeboid movement; diurnal rhythms, etc.

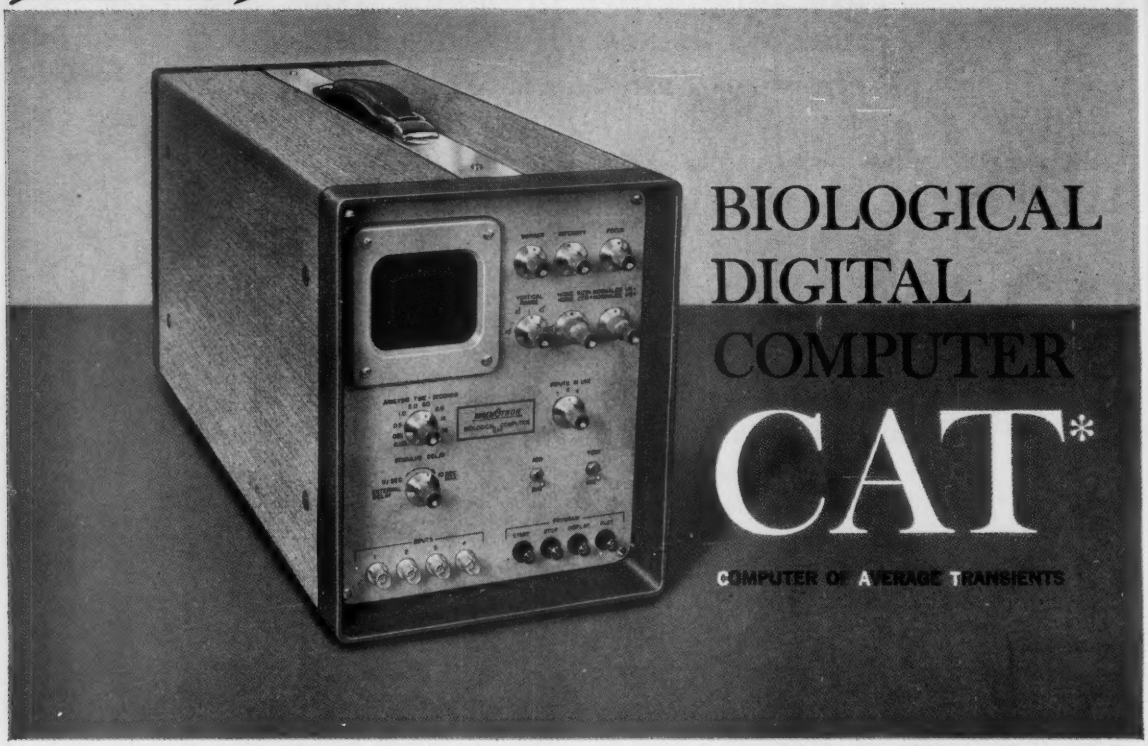
New (2nd) Edition—Ready in July!
About 864 pages
6½" x 10"
with about 271 charts, graphs, & diagrams
(Gladly Sent to Teachers on Approval)

A Saunders Book

W. B. SAUNDERS COMPANY
West Washington Square Philadelphia 5, Pa.

SCIENCE is published weekly by the AAAS, 1515 Massachusetts Ave., NW, Washington 5, D.C. Second-class postage paid at Washington, D.C., and additional mailing office. Annual subscriptions: $8.50; foreign postage, $1.50; Canadian postage, 75¢.

MNEMOTRON OPENS A NEW EPOCH FOR BIOLOGICAL DATA PROCESSING



for simultaneous, on-line calculation of average evoked responses of several variables

The Mnemotron CAT is a small, portable digital computer for the study of biological variables. It is the first biological computer specifically designed for biological scientists and it advances the technology in one giant step. No larger than the standard oscilloscope and weighing only 20 lbs., the CAT is a powerful tool for the biological scientist for the efficient study of the behavior of the many variables of living organism.

The CAT computer calculates the average response to repeated events and can do this *simultaneously for four different variables.* It is thus ideal for the simultaneous observation of average evoked brain potentials from four different regions of the brain. The CAT computer may be used for averaging evoked responses in the brain, nerve potentials, retinograms, cardiological data, phonocardiograms, autonomic functions, pupil responses and many other biologic variables.

Price: $9,950 (rental plan available)

Complete specifications available upon request. Write for Descriptive Bulletin.

* The perfect combination that achieves the ultimate in securing vital information and then recording it for future and constant reference.

Write for complete application, price and delivery information on Mnemotron Analog Data Tape Systems and Computers.

Complete, ANALOG TAPE RECORD/REPRODUCE* 4 CHANNEL SYSTEM

MNEMOTRON MODEL 204

0.2% precision at a low price! Mnemotron offers a unique pulsed FM principle and fully transistorized, self-contained unit that records all analog data • data acquisition • storage, analysis and reduction • time scale contraction and expansion • programming • computer read IN and read OUT • dynamic simulation. With Mnemotron, you can do more with paper recorders . . . expanding frequency response and channel capacity, saving you from being deluged with data, permitting you to look at the same data at different time scales. Complete with tape transports, $2,950

MNEMOTRON CORPORATION

Precision Analog Data Tape Recorders and Biological Computers.

MNEMOTRON CORPORATION • 39 South Main St., Pearl River, N.Y. • PEarl River 5-4015 (914) • Cables: Mnemotron

2 June 1961, Volume 133, Number 3466 **SCIENCE**

Editorial Stanford Accelerator Again 1737

Articles Scientific Applications of Nuclear Explosions: *G. A. Cowan* 1739
Nuclear explosions are uniquely necessary for a number of interesting experiments in basic research.

In Defense of Biology: *B. Commoner* 1745
The integrity of biology must be maintained if physics and chemistry are to be properly applied to the problems of life.

Cerebral Organization and Behavior: *R. W. Sperry* 1749
The split brain behaves in many respects like two separate brains, providing new research possibilities.

Science in the News The State of the Union Message: Money for Space; Some Implications for Economics and Education 1758

Book Reviews D. Joravsky's *Soviet Marxism and Natural Science, 1917–1932*, reviewed by *T. Dobzhansky*; other reviews 1762

Reports "Bioconvection Patterns" in Cultures of Free-Swimming Organisms: *J. R. Platt* 1766

Recording of Single Unit Activity in Isolated Central Nervous Tissue: *A. Ames III* and *B. S. Gurian* 1767

Strontium-90 and Cesium-137 in North American Milk: *J. L. Kulp* et al. 1768

Transport of Oxygen through Hemoglobin Solutions: *J. H. Wang* 1770

Response Latencies of Female Rats during Sexual Intercourse: *G. Bermant* 1771

Sparing of Folinic Acid by Thymidine: *N. Grossowicz* and *F. Mandelbaum* 1773

Association Affairs Pacific Division Meeting; Two New Affiliates 1774

Departments Forthcoming Events 1778

Cover Radial view of the outer bark of a 2-year-old white pine twig, fixed in osmium. The material showing is mainly bark cell wall, distorted by pressure of growth. (Electron microscope, about × 9400). [Johnson Parker, Yale University; Delbert E. Philpott, Woods Hole Marine Biological Laboratory]

Massachusetts Institute of Technology

OPERATIONS EVALUATION GROUP

Venturing Beyond the Confines of Your Discipline

The ultimate argument of the diplomat is still the threat of force; the conduct of war is still the business of the soldier and sailor. But in this era of sensitive political situations and nuclear peril, the immense complexities of armed combat have placed a few scientists in positions of uncommon responsibility.

Imaginative scientists and mathematicians with advanced degrees are invited to share in this uncommon responsibility with the staff of the Operations Evaluation Group of the Massachusetts Institute of Technology. Specifically you will provide the Chief of Naval Operations and Fleet commanders with an analytical basis for decision making on matters of tactics, strategy, composition of forces, employment of weapons and equipment, and research and development needs.

The appointments are permanent and well remunerated, and the peripheral benefits are indeed worth exploring.

Direct your inquiry to: Dr. J. H. Engel

M.I.T.

OPERATIONS EVALUATION GROUP
Massachusetts Institute of Technology
Washington 25, D. C.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

2 June 1961, Volume 133, Number 3466

SCIENCE

AMERICAN ASSOCIATION
FOR THE
ADVANCEMENT OF SCIENCE

Board of Directors

CHAUNCEY D. LEAKE, *Retiring President, Chairman*
THOMAS PARK, *President*
PAUL M. GROSS, *President Elect*

HARRISON BROWN — DON K. PRICE
HENRY EYRING — ALFRED S. ROMER
H. BENTLEY GLASS — WILLIAM W. RUBEY
MARGARET MEAD — ALAN T. WATERMAN
PAUL A. SCHERER, *Treasurer*
DAEL WOLFLE, *Executive Officer*

Editorial Board

KONRAD B. KRAUSKOPF — H. BURR STEINBACH
EDWIN M. LERNER — WILLIAM L. STRAUS, JR.
PHILIP M. MORSE — EDWARD L. TATUM

Editorial Staff

DAEL WOLFLE, *Publisher* — HANS NUSSBAUM, *Business Manager*

GRAHAM DUSHANE, *Editor*

JOSEPH TURNER, *Associate Editor* — ROBERT V. ORMES, *Managing Editor*

ELLEN E. MURPHY, *Assistant Editor*

NANCY TEIMOURIAN, *Assistant to the Editor*

News: HOWARD MARGOLIS

Book Reviews: SARAH S. DEES

Editorial Assistants: NANCY S. HAMILTON, EDGAR C. RICH, BARBARA SUTHERLAND, CONRAD YUNG-KWAI

Staff Assistants: GENEVIEVE M. KIRBY, PATRICIA D. PADDOCK, LOIS W. WOODWORTH

Advertising Staff

EARL J. SCHERAGO, *Director*

BERNICE SCHWARTZ, *Production Manager*

Sales: RICHARD L. CHARLES (New York, N.Y., PE 6-1858); C. RICHARD CALLIS (Old Bridge, N.J., CL 4-3680); HERBERT BURKLUND (Chicago, Ill., DE 7-4973); DILLENBECK-GALAVAN (Los Angeles, Calif., DU 5-3991)

SCIENCE, now combined with THE SCIENTIFIC MONTHLY, is published each Friday by the American Association for the Advancement of Science at National Publishing Company, Washington, D.C. SCIENCE is indexed in the *Reader's Guide to Periodical Literature.*

Editorial correspondence should be addressed to SCIENCE, 1515 Massachusetts Ave., NW, Washington 5, D.C. Manuscripts should be typed with double spacing and submitted in duplicate. The AAAS assumes no responsibility for the safety of manuscripts. Opinions expressed by authors are their own and do not necessarily reflect the opinions of the AAAS or the institutions with which the authors are affiliated. For detailed suggestions on the preparation of manuscripts, see *Science* **125**, 16 (4 Jan. 1957).

Advertising correspondence should be addressed to SCIENCE, Room 1740, 11 West 42 St., New York 36, N.Y.

Change of address notification should be sent to 1515 Massachusetts Ave., NW, Washington 5, D.C., 4 weeks in advance. Furnish an address label from a recent issue. Give both old and new addresses, including zone numbers.

Annual subscriptions: $8.50; foreign postage, $1.50; Canadian postage, 75¢. Single copies, 35¢. Cable address: Advancesci, Washington.

Copyright © 1961 by the American Association for the Advancement of Science.

Stanford Accelerator Again

Approval by the White House two years ago of plans to build the world's largest linear accelerator completed a chapter in the efforts to finance this instrument, but did not complete the book. The accelerator would be built at Stanford University and the cost is now put at $114 million. Responsibility for the program was assigned to the Atomic Energy Commission, but efforts to get the Joint Congressional Atomic Energy Committee to approve funds for construction have so far proved unsuccessful and the matter is now again before the committee. To assure a balanced research program in the face of such costly instruments, the White House science advisers had developed the theory that administrative planning for this and comparable expected expenditures should be carried out at an interagency, interdepartmental level. This was done, but with the assignment of the program to the AEC and the consequent need for approval by the Joint Committee, the program has got caught up in questions not directly related to the assessment of our research requirements

In the Joint Committee's deliberations last year, for example, some Democrats were prepared to be unenthusiastic about funds for construction of the accelerator to the extent that they experienced opposition to their own plans to provide the nuclear power reactor at Hanford, Washington, with generating equipment. The electricity produced would be used in the public power program of the Bonneville Power Administration. Democrats on the committee were also reluctant to provide Nixon, then Vice-President, with campaign opportunities in the form of ground-breaking ceremonies. There was also some lack of a sense of urgency for the accelerator in the AEC itself, perhaps because of resentment at being told what to do by people outside the commission.

These factors were, it is true, only in the background. In the foreground was the Joint Committee's concern with the proper assessment of our research needs. If the Eisenhower Administration took several years to convince itself of the wisdom of this expenditure, we should not be surprised that a Congressional committee finds it necessary to convince itself in turn. Questions still under consideration include: How much high-energy physics do we need? Does the Stanford accelerator best meet this need? What relationship will exist between Stanford and the AEC? Putting the foreground against the background, the result of last year's deliberations was that, although no money was provided for construction, $3 million was forthcoming for studies preliminary to construction. Since these studies had to be made in any event, the claim was that this small appropriation would not actually delay the program.

As matters stand this year, generating equipment for the Hanford power reactor is in the Kennedy budget, the political campaign is over, and the accelerator, according to informed sources, has been delayed about 6 months. The AAAS, incidentally, has participated in this seeking of funds, if only by providing a bit of the scenery. The original announcement by Eisenhower that he favored the accelerator was made at a AAAS symposium on the support of basic research and obstacles to that support. These particular obstacles now seem to have dissolved, although perhaps a different strategy by the Administration might have avoided them in the first place. The chances are that when the Joint Committee makes its report to Congress, probably by the end of this month, it will recommend funds for construction.—J.T.

Need light of specific wavelengths?

Here are three ways
Bausch & Lomb makes it easy for you

- **B&L INTERFERENCE FILTERS**

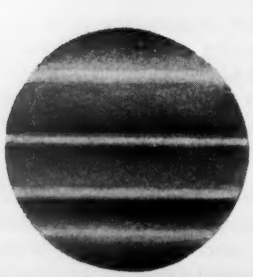
  Lowest-cost way to fit the wavelength to your need. Choose from our wide stock of standard filters, to transmit light from near ultra-violet (340mμ) to near infra-red (800mμ).

- **B&L CERTIFIED-PRECISION DIFFRACTION GRATINGS**

  Designing an instrument? Here's what you need to split light into all its component wavelengths—with greater resolution than by any other means. Choose from the world's largest selection of the most precise gratings ever made.

- **B&L GRATING MONOCHROMATORS**

  Just turn a dial to set the built-in grating to the wavelength you need. That's all there is to it! You get pure, intense light anywhere in the spectrum from ultra-violet into infra-red.



BAUSCH & LOMB
SINCE 1853

Made in America,
to the world's highest standards

BAUSCH & LOMB INCORPORATED
64218 Bausch Street, Rochester 2, N. Y.

Please send me:

- ☐ Interference Filter Catalog D-248
- ☐ Grating Catalog D-261
- ☐ Monochromator Catalog D-259

NAME .....

TITLE .....

PROFESSIONAL ADDRESS .....

.....

.....

2 June 1961, Volume 133, Number 3466 SCIENCE

CURRENT PROBLEMS IN RESEARCH

Scientific Applications of Nuclear Explosions

Nuclear explosions are uniquely necessary for a number of interesting experiments in basic research.

George A. Cowan

In the first week in July 1959, scientists of various specialties were invited to Los Alamos to discuss the topic "Scientific Applications of Nuclear Explosions." This subject is more narrowly defined than Project Plowshare, which embraces all of the peaceful uses of nuclear explosions, with emphasis on those of predominantly economic importance. It would be very unfashionable to pass up an obvious acronym for the enterprise, and so, to distinguish the purely scientific applications, the term *Project SANE* has been used at Los Alamos.

The meeting was restricted, chiefly to permit the free discussion of design details of nuclear devices under existing information security rules. In recent months some aspects of the topic have been discussed in other reports and journals, and part of the proceedings of the Los Alamos conference has been made widely available on an unclassified basis. Probably as a result, inquiries have been received from outside the Laboratory which indicate a general interest in the subject. In addition current planning for seismic calibration tests with nuclear devices includes proposals for basic research in other scientific fields. Therefore, it seems timely to offer the following brief account of the background and current status of some of these research proposals.

The author is associate division leader, Test Division, Los Alamos Scientific Laboratory, University of California, Los Alamos, N.M.

Why Nuclear Explosions?

Nuclear explosions are of interest to the research scientist chiefly as uniquely intense sources of neutrons, neutrinos, plasmas, high temperatures, gamma rays, x-rays, light, shock, and radioactive isotopes. In past years, suggestions have been made periodically for experiments which exploit one or another of these properties. However, during much of this busy period the implementation of such suggestions was not extensive.

Many factors have limited scientific experiments with nuclear explosions. These have included the almost total commitment, in the past, of weapon-laboratory efforts to immediate military needs, the difficulty and expense of field operations, and the restriction of detailed information on the properties and occurrence of nuclear explosions largely to those people most occupied with weapon development. In addition, the experience of performing a complex experiment at a test site and making sure that it will work the first and, perhaps, only available time is enough to persuade most scientists to obtain their data at home in the laboratory if it is at all possible to do so. Consequently, suggestions for making such measurements have not received much attention unless they appeared to have more than ordinary significance and could be performed only with a nuclear explosion and in connection with a scheduled test. Even then, only a very few such experiments have been carried out. However, in recent years an increasing amount of time has been devoted to an examination of the constructive potentialities of these explosions, and at Los Alamos this has resulted in a serious effort to further exploit new opportunities for purely scientific investigations.

Examples of past research based on nuclear explosions help to illustrate the nature of the contribution that such devices can make. The most fundamental property of fission explosions is their ability to transform large fractions of a given element by neutron reactions. An extreme example of this effect was encountered in the 1952 Mike thermonuclear explosion, in which a significant amount of uranium-238 was more than 99 percent destroyed and products of neutron capture of up to mass number 255 were observed (*1*). As a result, radiochemists from three collaborating laboratories identified two new elements (einsteinium and fermium) and greatly expanded existing information on neutron-rich nuclides in the transplutonic region. It was noted that some features of a thermonuclear bomb resemble those hypothesized for exploding supernovae (*2*). The nuclide californium-254, with a spontaneous fission half life of 56 days, was discovered and soon became associated with hypotheses concerning the decay of light from supernovae and mechanisms for nucleogenesis. The fact that neutron-capture cross sections have to remain high even at large neutron ex-

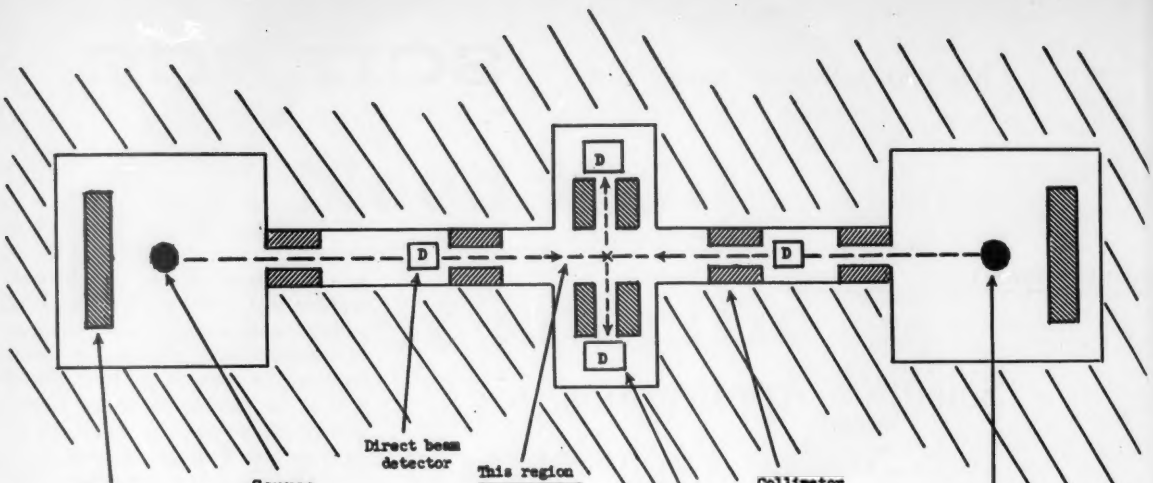


Fig. 1. A proposed method for measuring the *n-n* scattering cross section. Intersecting neutron beams from two 10-kiloton nuclear explosions in an underground tunnel are used. [W. N. Hess]

cess to produce uranium-255 in the amount necessary to account for the fermium-255 measured in the Mike explosion has led to the observation that present mass equations cannot properly be extrapolated to very-neutron-rich nuclides (*3*).

Investigation of the decay schemes of uranium-237, uranium-240, and neptunium-240 has been made possible with samples prepared from nuclear explosion debris (*4*). Similarly, samples from debris have been used to measure the fission cross section of uranium-237. The production of unique radioactive nuclides in quantity sufficient to permit measurement of the rate of world-wide fallout was effected in the nuclear devices exploded in the 1958 Hardtack program; the distribution in fallout of rhodium-102, which was deliberately produced in the very-high-altitude Orange test, is still contributing information on the transport of material deposited in the upper atmosphere. The effects of the high-altitude Argus, Teak, and Orange bursts in 1958, to the extent that they were observed, offered some stimulating data on the interaction of photon, electron, and debris fluxes with rarefied air and the geomagnetic field.

For experiments with neutrons resolved in energy by time-of-flight, an exploding nuclear device offers a very sharply pulsed source (< 1 μsec) of approximately 10^{23} neutrons per kiloton (TNT equivalent energy). This performance may be compared with that of the most advanced laboratory facility we know, which is planned to produce a sharply pulsed over-all source strength of approximately 10^{18} neutrons per second. Thus, the nuclear explosion of a 1-kiloton device is equivalent to approximately 300 years' operation of the laboratory machine. To take advantage of this tremendous flux, a bomb source of neutrons was utilized at Los Alamos during the 1958 tests to measure the symmetry of fission in uranium-235 at many individual resonances in the energy region from 10 to approximately 60 kev (*5*). The potential of this kind of experimental facility in the field of neutron spectroscopy has been enthusiastically described by Hughes (*6*).

Reviews and Conferences

Other possibilities have been considered at this laboratory. In 1957 a classified Los Alamos report was published in which A. Peaslee compiled suggestions from several staff members and consultants (*7*). These included a proposal by S. Chandrasekhar for the measurement of the time-history of excitation of an initially cold gas (for example, Ca or Fe vapor) by high-temperature radiation such as is observed in the corona and high-level chromosphere during periods of high solar activity and in the stellar envelope during a nova-like outburst. Froman and Ulam explored in a little detail the problem of using nuclear explosions for shock-tube and wind-tunnel studies. Taschek briefly mentioned a list of possible experiments, including production of large amounts of short-lived fission products and of transplutonium isotopes in milligram quantities for cross-section measurements; external target irradiations at high neutron flux; tracer experiments in meteorology; experiments of astrophysical interest involving measurements of equations of state and atomic spectra under extreme conditions of ionization, temperature, and pressure; and a study of various nuclear reactions which can be made to occur only under conditions existing in stars and thermonuclear explosions. Tuck considered schemes for observing the interaction of fireball plasmas with magnetic fields. Ulam discussed certain experiments in hydrodynamics, emphasizing the need for information concerning turbulence inside fireballs and possible techniques for producing asymmetric explosions. Interest in the latter subject was promoted by Ulam's suggestion for propelling a large space vehicle with nuclear explosions, a proposal which led to the current investigation called Project Orion.

In the spring of 1959 the Project Plowshare symposium, sponsored at San Francisco by the Lawrence Radiation Laboratory and the Atomic Energy Commission, included a program of papers on scientific experiments (*8*). The topics discussed included the use of nuclear explosions for investigations in neutron spectroscopy, multiple-neutron-capture experiments, studies of debris movement by labeling with unique tracers, scattering measurements with polarized neutrons, measurements of Schwinger scattering and neutron-electron scattering, studies of the interaction of microwave radiation with ionized air, the investigation of certain seismological questions, applications to a number of meteorological problems, and studies of interesting interactions of the products of bomb explosions with the upper atmosphere and magnetic fields.

The Los Alamos meeting provided an opportunity for a somewhat more extended and critical consideration of very much the same subject matter. Conference participants considered experiments in the fields of nuclear physics and nuclear chemistry, meteorology and upper-atmosphere physics, "space" physics, hydrodynamics, and solid-state physics. The roster of invited guests included experts in each of these fields, in order to provide informed comment on the various proposals. Usually rather long discussions followed each talk or group of talks on a given subject. Occasionally there seemed to be general agreement concerning the special merit of a proposal. Most of the talks are summarized in the following paragraphs, although classified details are necessarily omitted.

Experiments in Nuclear Physics and Chemistry

The measurement of the *n-n* scattering cross section seems achievable if nuclear explosions are used as a neutron source. Wilmot N. Hess described the results of some calculations on a possible experimental arrangement (Fig. 1). Two underground 10-kiloton explosions, detonated simultaneously at stations 60 meters apart, would be arranged so as to provide intersecting, collimated neutron beams, and the scatters would be observed as a function of time at right angles to the beam. A precision measurement of scattered neutrons in the energy region 1 to 5 Mev seems feasible if the background from neutrons multiple-scattered into the detectors from walls can be eliminated. Thermalization of the neutron beam to 10 kev is conceivable, but the background problem will get worse. The significance of this measurement is that if charge independence and charge symmetry of nuclear forces are violated, or if effects like the dipole interaction of magnetic moments hypothesied by Schwinger are significant, then the *n-n* singlet scattering length may be expected to differ from the corresponding *p-p* singlet scattering length by a small amount. Doubts were expressed during the discussion about the tractability of the background problem.

The search for improved resolution in neutron spectroscopy and the contribution that can be made by nuclear explosions were described by the late Donald J. Hughes (Fig. 2). Neutron spectroscopy provides a detailed view of the levels in many nuclei in a narrow band (approximately 1 kev) at an excitation slightly above the neutron binding energy (5 to 8 Mev). In this excitation band the level spacing is typically a few volts for medium-weight elements. By measurement of resonances in neutron cross sections, it is possible

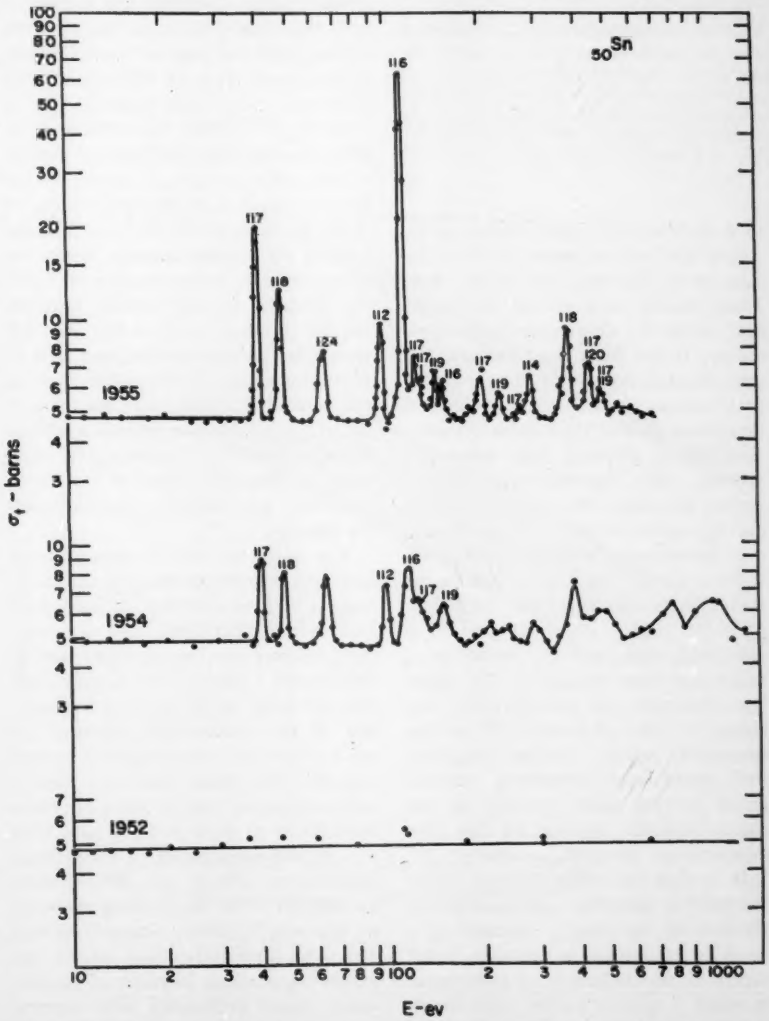


Fig. 2. Improved resolution in neutron spectroscopy is illustrated by the changes in the measured cross section of tin between 1952 and 1955. The use of nuclear explosions as pulsed neutron sources can provide another large increase in resolution. [D. J. Hughes]

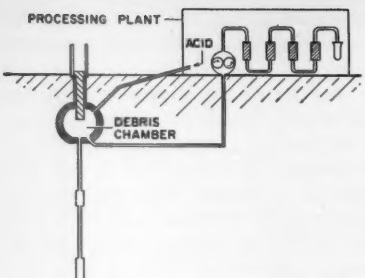


Fig. 3. Underground nuclear explosions can be designed to produce new elements by multiple neutron capture on uranium or plutonium. A processing plant on the surface would quickly recover and chemically identify new nuclear species. [G. A. Cowan]

to determine total level widths, partial widths for various modes of de-excitation, level spacing, and level spins. These results have played an important part in the development of nuclear theory. It has been demonstrated that nuclear explosions will provide external neutron fluxes many orders of magnitude greater than those presently available, or planned, from laboratory sources. No insurmountable experimental problems are foreseen in the use of explosions for making all neutron spectroscopy measurements of interest, with the exception of gamma-ray coincidence measurements. Some experiments which might be performed first with such sources would be a really complete analysis of the resonance behavior of uranium-233, uranium-235, and plutonium-239 in the resonance region. Hughes suggested that about two 10-kiloton neutron pulses a year could provide all the source strength needed for his own experimental program.

In a classified paper Edward Teller described a theoretical approach to the problem of maximizing exposure of a given target element to neutrons. Teller suggested an underground experiment in which a relatively small yield device would produce, at a minimum, 1 microgram of product of mass number 259 and a detectable amount of product of mass number 261.

I presented a classified paper in which it was disclosed that, just prior to the test moratorium, Los Alamos had already begun an experimental effort designed to produce new heavy elements. An existing weapon test in the 1958 Hardtack series was slightly modified to include a region of high neutron flux. Failure of a vital component spoiled the experiment, and further work on the program was terminated by the moratorium. However, it seems quite clear that, with presently known and tested designs, detectable quantities of elements of mass number greater than 260 can be made in devices of relatively low total yield. To avoid atmospheric contamination and to permit rapid recovery and processing of a significant fraction of the debris, it is desirable to explode such devices underground (Fig. 3). Multiple-capture products of the heavy elements can be built by long-term bombardment in piles, but the element-building process is terminated as soon as the lifetime for spontaneous fission and other modes of decay becomes short compared with the lifetime for neutron capture. Heavy-ion bombardments offer a means of building elements of high atomic number, but the products made in this way will always be on the neutron-poor side of greatest element stability rather than on the neutron-rich side. Thus, the thermonuclear explosion can provide a unique insight, otherwise unobtainable, into what is presently believed to be a principal cosmological element-building process.

The extrapolation of known decay and spontaneous fission systematics to unknown, new elements of very high mass number has been used to predict the half-lives of these nuclides and to help identify them. J. D. Knight summarized some of the predicted properties of the undiscovered elements. On the basis of the usual empirical extrapolations, little hope exists for chemically separating and identifying even-even nuclei of mass much greater than 256 or odd-mass nuclei of mass much greater than 259 or 261. This implies an effective limit on building elements in this way at about element number 102. The limit is imposed by the apparent exponential increase of spontaneous fission probability with increasing mass. However, no basic reason is known for excluding the possibility that a region of increasing stability exists, and one might hope to find elements with longer lifetimes before reaching the ultimate limit of successive neutron captures by uranium at about mass number 276, or by nuclei of higher atomic number at even greater mass number. [Indeed, recent work (*9*) indicates the possibility that even at an atomic number of 106, the half-life for spontaneous fission will be many years.]

Meteorology and Upper-Atmosphere Phenomena

L. Machta discussed the two prime applications of nuclear explosions for research in meteorology—to produce tracer activity and to affect the atmosphere by heat or ionization. Studies of transport of radioactivity from previous tests have strongly supported the suggestion that north-south circulation exists in the stratosphere. Some questions which might be studied in the future concern the paths of specific air currents in the stratosphere, the chief regions for injection of stratospheric air into the troposphere, the principal transport mechanism in the stratosphere, and the nature of the "cross wind" transport in the vicinity of the jet stream. Heat from nuclear explosions may be used to study two problems of interest in meteorology—the rise of hot gas bubbles and the effect on the atmosphere of a disturbance convection in the presence of natural convection. Radiations from nuclear explosions also change the electrical conductivity of large masses of air over great distances. Possible important effects of such disturbances have not yet been studied under controlled conditions.

In a paper which remains classified because of some weapon-performance data, E. A. Martell reviewed what is presently known about the mixing history of nuclear debris in the stratosphere and the rate and extent of fallout. He emphasized the need for information concerning debris storage times for altitudes up to several earth radii, and the use of nuclear explosions to supply tracers for these measurements. He also pointed out that, in order to limit fallout, studies in the lower atmosphere might be made with short-lived radioisotopes in small quantity or with naturally occurring sources of radioactivity.

In a group of three classified papers, the phenomenology of the Teak and Orange shots (megaton yield devices

exploded in midsummer of 1958, at altitudes of 252,000 and approximately 100,000 feet, respectively) was described, and the scientific questions concerning upper-atmosphere physics which might be answered by similar experiments were catalogued. For instance, Herman Hoerlin pointed out that many aspects of natural auroral phenomena can be simulated by nuclear explosions. Of particular interest would be the extensive observation of the interaction of debris particles with fields in space, with the geomagnetic field, and with the upper atmosphere, and observation of the effects on the radiation belts. Thomas B. Cook, Jr., evaluated the scientific return from a low-yield device exploded at the edge of the atmosphere (Fig. 4). Since energy deposition occurs in three distinct zones of the atmosphere, and at three well-spaced times, from x-ray, neutron and gamma-ray, and debris-particle interactions, respectively, the separate excitations can be studied in considerable detail, preferably by land-based optical instrumentation. Philip L. Randolph presented a detailed theoretical description of the effect on the ionosphere of one megaton of x-ray energy released at 10^5 kilometers from the earth and at the moon. Measurement of the dependence of reflection of various radio frequencies on time and altitude would produce valuable information on the mechanism of recombination of electrons and the decay rate of a perturbation in the ionosphere.

Physics in Space

Two talks were delivered on some possible effects which might be observed as the result of bomb explosions in outer space. Thomas Gold expressed an interest in studying shock waves in space when the input is exactly known. In the vicinity of the sun, shock waves are accompanied by a narrow-band radio noise corresponding to the plasma frequency. Observation of a similar phenomenon in a bomb explosion would add important information to what is presently known about this unexplained effect in solar physics. The possibility of disturbing the geomagnetic field and letting otherwise unobserved particles in space reach the earth, the production of phenomena similar to "whistlers," and uses for the sharp pulse of light or of radio frequencies from a bomb as a radar device were also mentioned.

C. L. Longmire called attention to the probable stability of the bomb debris as a plasma cloud in space and discussed some of the interesting properties of such a cloud. Possible hydrodynamic, hydromagnetic, and radiation-pressure mechanisms exist for accelerating plasma particles in space to really high velocities. Plasmas from two bombs colliding will probably produce turbulence and a magnetic field where none existed before. Hydromagnetic shocks may also be produced by such explosions, and it would be interesting to study their structure. A careful measurement of the electromagnetic signal could conceivably provide information concerning the magnitude of the field in space, particle density, and temperature. In connection with the possible acceleration of bomb debris by radiation pressure, Andrew Skumanich presented calculations which indicated that this mechanism would be unimportant by comparison with hydrodynamic acceleration.

Some novel suggestions were made for using the vacuum and limitless distances of space as a physics laboratory for measuring some of the fundamental physical constants with greater accuracy than would be possible in a terrestrial laboratory. Freeman Dyson explained that a very accurate measurement of the lifetime of the free neutron would help test the validity of various ideas concerning a universal theory of weak interactions between elementary particles. If two rocket-borne neutron detectors a few thousand kilometers apart measured the neutron flux from a nuclear explosion in space, attenuation of the flux would occur because of neutron decay during flight between the detectors. In principle, a highly precise measurement of the

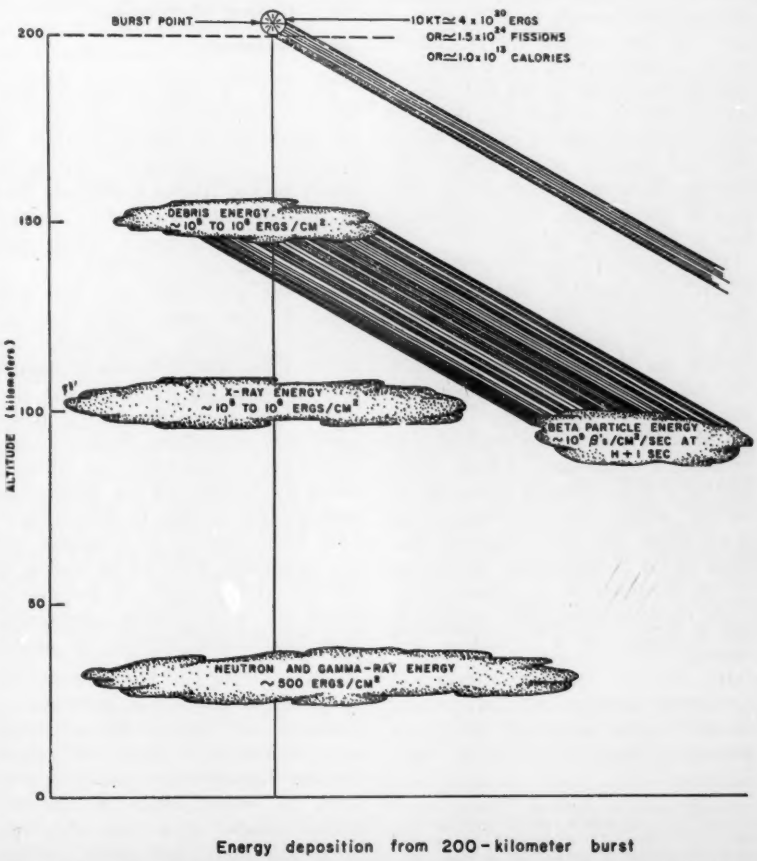

BURST POINT
1 KT ≃ 4 × 10^19 ERGS
OR ≃ 1.5 × 10^24 FISSIONS
OR ≃ 1.0 × 10^13 CALORIES
200
150
100
50
0
ALTITUDE (kilometers)
DEBRIS ENERGY ~ 10^8 TO 10^9 ERGS/CM^2
X-RAY ENERGY ~ 10^9 TO 10^8 ERGS/CM^2
BETA PARTICLE ENERGY ~ 10^8 β's/CM^2/SEC AT H + 1 SEC
NEUTRON AND GAMMA-RAY ENERGY ~ 500 ERGS/CM^2
Energy deposition from 200-kilometer burst

Fig. 4. A 10-kiloton nuclear explosion at the edge of the atmosphere produces x-ray, neutron and gamma-ray, and debris particle interactions with air in three distinct zones at three different times. [T. B. Cook, Jr.]

decay time of the neutron could be made in this way. In a proposal based on a similar idea, Robert K. Squire suggested that the velocity of various frequencies in the electromagnetic spectrum might be measured by time-of-flight of photons from a nuclear explosion at about 10^6 kilometers from the earth. It was stated that the precision of the measurement would be greater by three orders of magnitude than the precision of present data, and the frequency range greater by approximately six orders of magnitude.

Hydrodynamics and Solid-State Studies

Dyson presented a scheme for containing nuclear explosions of up to 50-kiloton yield inside a box on the surface of the ground. Explosion of a large amount of dust, arranged to coincide with explosion of a nuclear device, could provide an efficient heat-sink for the nuclear energy. Heavy plates moving outward into a system of gasbags would take up the first impulse on the walls of the box, and the rapid drop in temperature of the gas would limit the duration of the initial high-pressure pulse to 1 millisecond. The cost of the structure might be several tens of millions of dollars.

Ulam described some hydrodynamic effects which could be initiated by nuclear explosions. He urged investigation of the possibility of producing ionized jets of very high velocity from "shaped" nuclear devices analogous to shaped high-explosive charges and discussed other ideas for the production of asymmetric explosions which could lead to a more efficient utilization of nuclear energy for propelling large space ships. He also suggested that many of the hydrodynamic phenomena in the explosion of a nuclear device might resemble those which accompany the explosion of a supernova and should be studied for their relevance to this problem in astrophysics.

G. J. Dienes offered some notes on the use of very high rates of irradiation with fast neutrons in the study of radiation effects on solids. For many known radiation effects, theory indicates a strong dependence on flux. One would like to produce at a given temperature a certain concentration of defects in a pulse no longer than about 10^{-4} second and study the subsequent motion, disappearance, and aggregation of these defects. Integrated exposures of 10^{17} neutrons per square centimeter, or higher, would be desirable. The use of such a source for investigating the annealing mechanism in metals, enhanced diffusion in metals, solid-gas chemical reactions, and some other phenomena of importance in the study of solid-state problems was discussed.

Some General Observations and Conclusions

Do any of these proposals merit serious consideration? The answer must be based on a difficult mixture of scientific and economic arguments, which the Los Alamos conference tried in part to anticipate, taken together with political arguments, which each reader will supply for himself.

On the affirmative side, one may conclude that some interesting and valuable scientific observations are uniquely available if nuclear explosions may be used for research, and that undoubtedly more thought will reveal more such possibilities. In many cases, radioactive contamination can be minimized by carrying out the experiments underground. In order to provide assurance against evasion of a possible test ban agreement, it should be feasible to conduct at least some of the experiments on a completely unclassified basis and actually increase the opportunities for cooperative research on an international scale.

Some of the nuclear explosions presently in the planning stage for purposes of improving seismic detection, or in connection with other Plowshare Program experiments, can also be used for purely scientific measurements. Perhaps the most easily realized and generally understood scientific use of a nuclear explosion is as a neutron source for external bombardments. If present ideas are carried out, the Project Gnome event (a 5-kiloton nuclear explosion in a salt dome near Carlsbad, New Mexico) will serve as such a neutron source for four sets of physics experiments performed by scientists from several Atomic Energy Commission laboratories. All of these will be experiments with energy-resolved neutrons to investigate various neutron-capture cross sections, the total cross section and fission cross section in several heavy elements, and the basic fission process. These and similar efforts will provide further opportunities to gage the potential usefulness of nuclear explosions in research (*10*).

References and Notes

1. A. Ghiorso, S. G. Thompson, G. H. Higgins, G. T. Seaborg, M. H. Studier, P. R. Fields, S. M. Fried, H. Diamond, J. F. Mech, G. L. Pyle, J. R. Huizenga, A. Hirsch, W. M. Manning, C. I. Browne, H. L. Smith, R. W. Spence, *Phys. Rev.* **102**, 180 (1956).
2. E. M. Burbidge, G. R. Burbidge, W. A. Fowler, F. Hoyle, *Revs. Modern Phys.* **29**, 547 (1957).
3. A. G. W. Cameron, *Can. J. Phys.* **37**, 322 (1959).
4. J. D. Knight, M. E. Bunker, B. Warren, J. W. Starner, *Phys. Rev.* **91**, 889 (1953); M. E. Bunker, B. J. Dropesky, J. D. Knight, J. W. Starner, B. Warren, *ibid.* **116**, 143 (1959).
5. G. A. Cowan, A. Turkevich, C. I. Browne, and Los Alamos Radiochemistry Group, *Phys. Rev.* **122**, No. 4 (1961).
6. D. J. Hughes, *Nucleonics* **18** (7), 54 (1960).
7. M. E. Battat, B. M. Carmichael, S. Chandrasekhar, D. Froman, A. T. Peaslee, Jr., R. F. Taschek, J. L. Tuck, S. Ulam, K. M. Watson, *Los Alamos Scientific Laboratory Report No. LAMS-2087* (classified).
8. "Second Plowshare Symposium, San Francisco, May 13–15, 1959," *Lawrence Radiation Laboratory Report No. UCRL-5679.*
9. D. W. Dorn, *Phys. Rev. Letters* **6**, No. 2, 80 (1961).
10. This study was made under the auspices of the U.S. Atomic Energy Commission.

In Defense of Biology

The integrity of biology must be maintained if physics and chemistry are to be properly applied to the problems of life.

Barry Commoner

A great deal has been said of late about the flourishing state of biology and its exciting progress toward the solution of basic problems. There would appear to be little need for a defense of biology, zoology, botany, or any other part of the sciences of life.

Certainly much of this is true. Remarkable progress has been made in our understanding of important biological processes: metabolism, photosynthesis, the biosynthesis of macromolecules, the structure of viruses. Yet certain equally fundamental questions that have long been of concern to biologists have firmly resisted the recent winds of progress. We still have but inadequate answers to the questions: What is the cause of speciation? How do cells differentiate? What processes dictate their division, growth, and cessation of growth? How does inheritance control these developmental processes? Obviously, some areas of biology are still making relatively slow progress.

A Divided Science

What distinguishes the slower areas of biology from those which seem to grow by startling jumps ("breakthroughs" in newspaper parlance) and which surround themselves with glamor? The fast-growing fields, which appear to represent the cutting edge of progress in biology, are those in which the biological problem has been reduced to chemical or physical terms. The slower-paced areas are those which have thus far largely resisted this advance. When a biological problem can be restated in molecular terms the enormously powerful insights and instruments of modern chemistry, physics, and engineering can be brought to bear on it. Under such a massive attack, quite rapid and sometimes spectacular discoveries are made.

Of course, there is a more homely way to distinguish between the two types of studies. In the fast-moving fields the laboratories are large and densely packed with expensive electromechanical apparatus, students, and postdoctoral fellows. In the other areas of biology, we see some microscopes (optical, that is), herbarium sheets, and fewer people.

From almost any viewpoint there seems to be a widening gap between the more traditional areas of biology and those which are closely related to modern chemistry and physics.

It is true, of course, that chemistry and physics have come to occupy an increasingly important place in *all* areas of biological research, including the traditional ones. But the levels of application current in the two segments of biology are vastly different. While investigations of the more traditional sort may concern themselves with *p*H or oxygen consumption, really modern biological studies feature semiconductors, charge-transfer complexes, radioisotopes, and information theory.

How well can such a divided science work? Will the very problems that attract the more glamorous laboratories be advanced, in the long run, in circumstances which preclude a close contact with taxonomy, evolution, and morphogenesis?

One view is that this separation is inevitable and healthy—that traditional biology has served its purpose and must now give way to biochemistry and biophysics. A recent review of Isaac Asimov's new book about modern biology states that "For him . . . biology is a system that proceeds from biochemistry to the associated subjects of neurophysiology and genetics. All else, as they used to say of the nonphysical sciences, is stamp collecting." "I happen to agree firmly with Asimov about what is central in science and what is not," the reviewer writes, "and I will defend him to the death against traditionalists who might deplore his not starting with 'Heat, Light, and Sound' or his giving short shrift to 'Natural History'" (*1*).

Having rarely been accused of being a traditionalist, perhaps I may be permitted to disagree with this view.

I believe that the increasing separation between "traditional" and "modern" biology is regrettable. In the narrow view, this process may have unfortunate effects on the number and competence of students in traditional departments of biology, zoology, and botany, and may be reflected in the level of support these departments command both within and without the university. But what is a far more serious matter is the harmful effect on science itself.

Process of Alienation

The view that biology is only an unresolved form of chemistry and physics is not new. Biology has always produced adventitious areas of investigation which quickly lose their contact with the mother science. So long as the chemistry of rubber was poorly understood, the problem of the role of latex in the plant, of its composition and properties, belonged to biology. As soon as chemistry had advanced sufficiently to deal with such a complex substance, the problem was taken over by biochemists, physical chemists, and engineers. Certainly we have gained from this process and our knowledge of rubber is vastly increased. But how much of this new knowledge has been reflected back upon plant biology?

A similar estrangement characterizes the history of research on starch. Classical plant morphologists have produced monumental works on starch grains, which have unique structural organization closely correlated with the plant's specific character. In more recent years an equally impressive body of knowledge about the chemical substances

The author is professor of plant physiology and chairman of the Committee on Molecular Biology at Washington University, St. Louis. This paper is his address as retiring vice president of the AAAS and chairman of the section on botanical sciences, presented at the annual meeting of the AAAS, New York, 27 Dec. 1960.

extractable from the starch grain—amylose and amylopectin—has accumulated. Moreover, enzymes that synthesize these substances have been isolated. Yet an analysis of the information available from studies of extracts shows that we do not understand how the enzymes could possibly account for the presence together in the starch grain of both amylose and amylopectin in proportions which are under genetic control. Clearly, our attention must now return to the developing starch grain, and we must learn how the enzymes are disposed within it, and how the cellular environment can give rise to a precise correlation between the two paths of biosynthesis that cannot be accounted for in terms of test-tube chemistry. The stage is set for a fascinating marriage between the classical studies of the starch grain and modern starch biochemistry and biophysics. But to my knowledge no proposals have been made, consummation is a distant prospect, and fruitful results are even more remote. Why? I believe that we can blame the unfortunate separation between the classical and the more modern aspects of biology.

I believe that there is some justification for a generalization: as soon as an interesting and important biological problem becomes susceptible to chemical or physical attack, a process of alienation begins, and the question becomes, in the end, lost to biology. But in each case, the purely chemical—or physical—studies run their course and come to the blank wall that still surrounds the intimate events which occur within the *living* cell. The obvious need is to return home to biology. But now the errant science has long forgotten its home, and the mother is too bewildered by its fast-talking offspring to be very happy about welcoming it back into the family.

Clearly, such a course of events cannot go on indefinitely, for there are, after all, only a limited number of substances and processes that can be removed without finally leaving nothing at all behind. So long as this process of alienation affected only the end products of metabolism (such as starch, rubber, or pigments), the parent science suffered some damage but no really lethal blow. But now biochemistry and biophysics have reached deep into the core of biology—to reproduction and inheritance—and the question arises as to how biology will sustain this more penetrating attack.

Biology under Attack

One view of the result of this latest event is readily obtained from the new volume that has already been referred to. The book is a summary of the present state of the biological sciences written for "the intelligent man." It opens with the following sentence: "Modern science has all but wiped out the borderline between life and non-life" (*2*).

Since biology is the science of life, any successful obliteration of the distinction between living things and other forms of matter ends forever the usefulness of biology as a separate science. If the foregoing sentence is even remotely correct, biology is not only under attack; it has been annihilated.

An explanation of the basis for this remarkable assertion is of course necessary, and it will, I believe, reveal that this statement is the crowning and wholly logical conclusion of a series of ideas which have attained considerable approval among scientists.

What evidence is offered in support of this statement? We can begin with Asimov's consideration of that marvelously meaningful problem that has for so long intrigued biologists: At what moment in the history of matter did life appear? The answer given is this: "Then, eventually, must have come the key step—the formation, through chance combinations, of a nucleic acid molecule, capable of inducing replication. That moment marked the beginning of life" (*2*, p. 542).

Why is this so? Because "All of the substances of living matter—enzymes and all the others, whose production is catalyzed by enzymes—depend in the last analysis on DNA" (*2*, p. 535).

Deoxyribonucleic Acid

This story is, of course, well known. The DNA molecule is a code which contains all the information required to specify the inheritable characteristics of the organism. The information is translated into protein structure by a process in which DNA dictates the specificity of protein synthesis. Once the information has been so translated, all of the chemical reactions of the cell —which are wholly determined by the structure of enzyme proteins—have also been specified. Moreover, the genes, which according to biological evidence regulate the inherited characteristics of a species, consist of DNA, and the self-duplication of DNA is the basis of genetics. In sum, DNA is the vehicle for the continuity of life.

All of us have heard this story told at every level of the ladder of scientific discourse, from research papers, through review articles to textbooks and the latest issues of the news magazines. The basic ideas are attractive and widely accepted in the scientific community. Many of us have heard them in the classroom—sometimes from our own lips. And so I must apologize—and hereby do—to our helpful author whom I have rudely represented as leader of an attack in which so many others participate.

But can it be true that the familiar "DNA story" is really an attack on biology? Let us return for a moment to the assertion that "the boundary between life and non-life has all but disappeared," for most of us will agree that, if this statement is not an attack on biology, it is at least a pretty fair insult.

If we agree both that nucleic acid is an encoded form of life, capable of self-duplication, and that it can bring about the translation of its own code into the remaining aspects of life, then it follows that, given a reasonably healthy environment, nucleic acid can indeed create life and perpetuate it. Since it is also indisputable that nucleic acid is a chemical substance, then we must agree (if all this is true) that life is essentially nothing more than an expression of the chemistry of nucleic acid. Following this closely reasoned logic, we end inevitably with the conversion of biology into the chemistry of nucleic acid and its creations.

Is Biology Worth Saving?

Now the problem is more evident. Biology *does* appear to be dwindling, and in need of defense. I believe that in the last decade every academic biologist has begun to feel the realistic effects of the atrophy of biology on the life of his laboratory, his classroom, and his institution. Twenty-five years ago, bright young people eager to conquer the world of science were proud to become biologists, to study *Drosophila* genetics, plant taxonomy, or embryology. Nowadays, a student with a budding interest in genetics often ends up mating strands of DNA rather than fruit flies, and greenhouses are built to grow plants for the purpose of pro-

ducing viruses. Bright young biologists, if they are good enough, become biochemists and biophysicists.

Biology does seem to be in some need of a defense. But is it worth saving? To be explicit, what I mean is this: Is there any good reason why we should resist the progressive isolation of taxonomy, morphology, physiology, and the rest of the "less exciting" fields from the areas that have apparently been won over to modern chemistry and physics?

I believe that this process should be resisted, not because the traditional fields of biology ought to be protected from the effects of chemistry and physics, but because unless biology itself survives, the great powers of these modern sciences cannot be fully used. I believe, for example, that the proper correlation of physics and biology requires that *the integrity of both sciences* be maintained in the collaborative process.

Part of the argument in support of this view has already been made: that in many instances the pursuit of a purely physical or chemical line of attack runs out of momentum and needs to return to the truly living system.

But the chief argument that I should like to propose is this: Analysis of living systems, based on modern physical and chemical theory, leads to the conclusion that life is unique and that it cannot be reduced to the property of a single substance or of a system less complex than a living cell. I propose to cite several examples of such analyses in order to show that fundamental theories of physics and chemistry support the view that there is, in modern science, no justification for the "obliteration of the boundary between life and non-life."

An interesting case in point is the matter of information theory, which now plays such an important role in proposals regarding the genetic function of DNA. The basic notion is well known: The DNA in the germ cell is supposed to contain in an encoded form all the information required to specify in detail the inheritable features of the adult organism.

Elsasser

Now this question has been given a searching examination by a distinguished physicist, W. M. Elsasser, in his book *The Physical Foundation of Biology* and in a subsequent article (*3*). While space does not permit even an approximate description of Elsasser's work, certain aspects of it can be simply stated. Elsasser points out that from recent advances in computer theory one can set certain fairly precise requirements on the above hypothesis. Two critical requirements are (i) The information content of the amount of DNA present in the germ cell of a complex organism, such as a horse, should greatly exceed that present in the cell of a more simple organism, such as an ameba. (ii) Cells should contain a device for translating the code library contained in the DNA into the biological characters which it determines; computer experience indicates that the translation device ought to be considerably more massive than the library.

The available facts suggest that living things do not meet these requirements: (i) Organisms which must differ considerably in their genetic complexity often have similar cellular DNA contents (*4*), and there is no evidence that the discrepancy can be accounted for by differences in genetic redundancy or in the inertness of some chromosome sections. Conversely, organisms which are nearly identical in genetic complexity may differ considerably in cellular DNA content (*5*). The available evidence does not support the idea of a one-to-one correspondence between genetic information and the information represented by the structure of DNA, or for that matter of any other molecular component of the cell. (ii) No cytologist has discovered a ubiquitous structure, considerably larger than the chromosomes (the code library) which shows evidence of serving as a translator. While recent biochemical evidence suggests possible means whereby DNA-borne information may be translated into genetically effective protein specificity, there is still no sign of a device capable of translating the DNA code into the numerous anatomical features (fingerprints, for example) that are also inherited.

Thus, a strict analysis of the problem of inheritance in accordance with modern information theory leads to the remarkable result that the organism's specificity must be determined, at least in part, by agencies not present in the initial germ cell and certainly not in the DNA alone. Elsasser points out that this view, which can be derived directly from modern physical theory, is identical with a principle already well established in biology—*epigenesis*. This view holds that the fertilized egg begins with a limited amount of specificity, which develops into more detail in progressive, superimposed, stages. Strong evidence from embryology supports this conclusion, and recently some investigators have suggested that certain specific types of inheritance, especially in protozoa, are epigenetic in character (*6*).

These results have an important bearing on the customary ideas about DNA, for they call into question the basic assumption that DNA (or for that matter any other single component of the germ cell) can possibly serve, by itself, as the final arbiter of biological specificity. There are many fascinating questions that arise from these considerations, but these will need to be taken up at another time.

Bohr

Another notable defense of life as something unique and distinct from non-life comes from one of the great physicists of our time, Niels Bohr. Bohr has written several remarkable papers (*7*) about the relation between biology and physics, which have for too long been neglected by biologists and biophysicists alike. One of Bohr's contributions to physics is the theory of complementarity, which holds, for example, that the electron is characterized by both particulate and wave properties, which are nevertheless mutually contradictory (the more precisely the wavelength is defined the less certain we become of the electron's position).

According to Bohr this relationship is an example of a *general* law of complementarity which applies as well to biology. Bohr suggests that complementarity regulates the relationship between two coeval aspects of biological systems: the existence of life in the whole intact cell, and the separate physicochemical events that occur within it. The more precisely we try to determine the internal events of a cell the more likely we are to destroy its life. Bohr concludes: "On this view, the very existence of life must in biology be considered an elementary fact, just as in atomic physics the existence of a quantum of action has to be taken as a basic fact that cannot be derived from ordinary mechanical physics."

Now, no one should conclude from

this statement that the property of life is somehow nonmaterial and innately mysterious. Bohr is not a vitalist. On the contrary, Bohr's principle simply serves as a warning that we cannot study the property of life without retaining it in our experiments. Again, this view raises a host of fascinating questions that we cannot go into here. It is pertinent here only to show that the penetrating insight of modern physical theory reveals certain inconsistencies in the notion that life can be reduced to the chemistry of some special substance.

Hinshelwood

An equally cogent analysis of the problem, this time from the viewpoint of the kinetics of complex chemical systems has been made by one of the founders of that field, Sir Cyril Hinshelwood. He points out that "the view that nucleoproteins are the basis of genes which could ever be self-replicating in isolation and merely in virtue of their structure is probably a dangerous over-simplification. . . . The picture presented is essentially static. The phenomena of growth, adaptation and reproduction need a dynamic one." From a straightforward analysis of the kinetic behavior of the complex metabolic processes of bacterial cells, Hinshelwood suggests an alternative source for the self-regulation of living cells. "The building blocks of the cells, wonderful as they may be as structures, are useless by themselves. Cell function depends upon the rhythm and harmony of their reciprocal actions: the mutual dependence of protein and nucleic acid; the spatial and temporal relations of a host of elementary processes which with their sequences and bifurcations make up the reaction pattern of the cell. A system of mutually dependent parts, each of which performs something like enzymatic functions in relation to another, will, as can easily be shown, in the steady state appear as a whole to be autosynthetic. No individual part need be credited with a new and mysterious virtue by which to duplicate itself" (*8*). In effect, it is Hinshelwood's view that nothing less complex than an entire cell is capable of *self*-duplication.

A True Alliance

These brief descriptions of the views of life developed by Elsasser, Bohr, and Hinshelwood reveal a considerable unanimity, and—what is perhaps more surprising—a remarkable agreement with the biologist's long-held opinion that life is inherently complex and unique. How can we explain this unexpected convergence of conclusions reached, separately, by such different routes as information theory, the theory of complementarity, the physical chemistry of complex systems, and the manifest properties of living things? I believe that what is common—and to some degree unusual—in these physical and chemical views of life is that they are profound. They apply modern physical and chemical theory to the problem of life with the same standards of depth and rigor that are required in the treatment of purely physical and chemical problems. Perhaps I am permitted to generalize: Whether the approach to the problem of life is through physics, through chemistry, or through biology itself, the results are consistent—provided that the analysis is fundamental and thorough.

Perhaps the remedy for the declining fortunes of biology is now clear. Biologists should not regard chemistry or physics as a nemesis but as an ally. If modern physical theory requires that epigenesis govern biological development, and if the cell theory can be deduced from physical chemistry, then physics and chemistry must be regarded as biology's most powerful friends.

If this mutual relationship is to bear fruit there must be a true alliance between real sciences rather than the creation of rootless hybrids. If we allow classical biology to decline, the full powers of modern physics and chemistry cannot be brought to bear on the study of life. I believe that in our university organization we must discover how to combine biology, chemistry, and physics in ways that will retain the integrity of each discipline.

A final point is in order, for the problem of the future of biology, however important to us, does not exist apart from the society in which we live. It appears to me that in the recent applications of science to social problems, there has been an increasing tendency to ignore the facts of life. Too often, we are prepared to expose miles of countryside to substances known chiefly for their power to kill. By the time we have dispersed insecticides, herbicides, fungicides, nematocides, pesticides, and other assorted agents, the adaptive latitude of the ecological environment, which is so vital to the success of plant, beast, and man, may have been fatally restricted. I sometimes think that the difficulties we now face in controlling water, air, and soil pollution, and the undue dissemination of radioactive materials, are the result of a common impression that "the boundary between life and non-life has all but disappeared." In fact, if we do not mend our ways, the statement may, after all, turn out to be true.

I believe that the time has come to restore the science of life. We need to do this for the sake of the science, and for the sake of that which is the goal of all science—the welfare of man (*9*).

References and Notes

1. D. J. de Solla Price, *Science* **132**, 1830 (1960), review of (*2*).
2. I. Asimov, *The Intelligent Man's Guide to Modern Science*, vol. 2, "The Biological Sciences" (Basic Books, New York, 1960).
3. W. M. Elsasser, *The Physical Foundation of Biology* (Pergamon Press, New York, 1958). See also W. M. Elsasser, *J. Theoretical Biol.* **1**, 27 (1961). I am indebted to Dr. Elsasser for illuminating discussions of these matters.
4. A. E. Mirsky and H. Ris, *J. Gen. Physiol.* **34**, 451 (1951); R. Vendrely and C. Vendrely, *Compt. rend.* **235**, 444 (1952).
5. F. Schrader and S. Hughes-Schrader, *Chromosoma* **7**, 469 (1956).
6. D. L. Nanney, *Cold Spring Harbor Symposia Quant. Biol.* **23**, 327 (1958).
7. N. Bohr, *Atomic Physics and Human Knowledge* (Wiley, New York, 1958).
8. C. Hinshelwood, *Proc. Roy. Soc. London* **B146**, 155 (1956).

9. In the development of the views put forward in this paper, I have had the benefit of research grants from the National Foundation, the National Science Foundation, and the Rockefeller Foundation.

Cerebral Organization and Behavior

The split brain behaves in many respects like two separate brains, providing new research possibilities.

R. W. Sperry

The control centers of the brain, including the cortical areas, come in matched pairs, right and left mirror mates, with a complete set to each side. Normally, right and left brain halves are in direct communication through a series of commissures, which are defined as fiber systems that cross the midline to form reciprocal cross-connections between corresponding structures on the right and left sides. The largest of these is the great commissure of the cerebral hemispheres, the corpus callosum, the general proportions of which are indicated in Fig. 1, with reference to the rhesus monkey, its relative size in man being somewhat larger.

The corpus callosum is the most massive by far of any single fiber tract in the brain. It was, therefore, cause for some concern that complete surgical section of the corpus callosum in human patients failed to produce any clear-cut functional impairments detectable even with extensive neurological and psychological testing. The discrepancy between the large size, strategic position, and apparent importance of the corpus callosum on the one hand, and the lack of functional disturbance after its section on the other, posed for many years one of the more intriguing and challenging enigmas of brain function.

During the past seven years or so the old "riddle of the corpus callosum" has been largely resolved, in animal studies in which it has been possible at last to demonstrate definite high-level integrating functions for this structure. More important, perhaps, the results have also opened some promising new approaches to the study of cerebral organization, significantly extending the general scope and analytic possibilities of the brain lesion method and related techniques. The following is a generalized survey of some of these developments.

The animal studies from the beginning have confirmed the earlier clinical observations that complete section of the corpus callosum produces surprisingly little disturbance of ordinary behavior. Callosum-sectioned cats and monkeys are virtually indistinguishable from their normal cagemates under most testing and training conditions. This tends to be the case also with further midline sections added, even to the extent of including all the structures labeled in Fig. 1, plus the cerebellum.

Except for causing partial loss of vision, these midline cuts leave nearly all the sensory inflow, motor outflow, and other brain-stem relations intact, and they leave most of the internal organization of each hemisphere undisturbed. Aside from manifesting an initial tremor and unsteadiness when the cerebellum is bisected, monkeys recovered from such midline surgery show no disabling paralysis, ataxia, or spasticity. There is no forced circling, nor are there other asymmetries. The animals are not overly hyperactive or lethargic. Visceral and other homeostatic functions continue as before. The monkeys remain alert and curious and retain fair-to-good muscular coordination. They perceive, learn, and remember much as normal animals do.

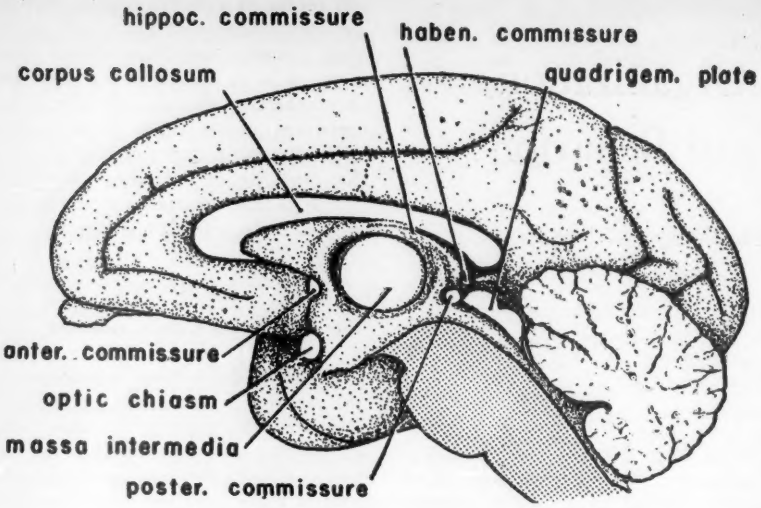
However, if one studies such a "split-brain" monkey more carefully, under special training and testing conditions where the inflow of sensory information to the divided hemispheres can be separately restricted and controlled, one finds that each of the divided hemispheres now has its independent mental sphere or cognitive system—that is, its own independent perceptual, learning, memory, and other mental processes. It is as if each of the separated hemispheres is unaware of what is experienced in the other, as if neither has any direct memory of anything that has gone on in the other subsequent to the midline surgery. In these respects it is as if the animals had two separate brains.

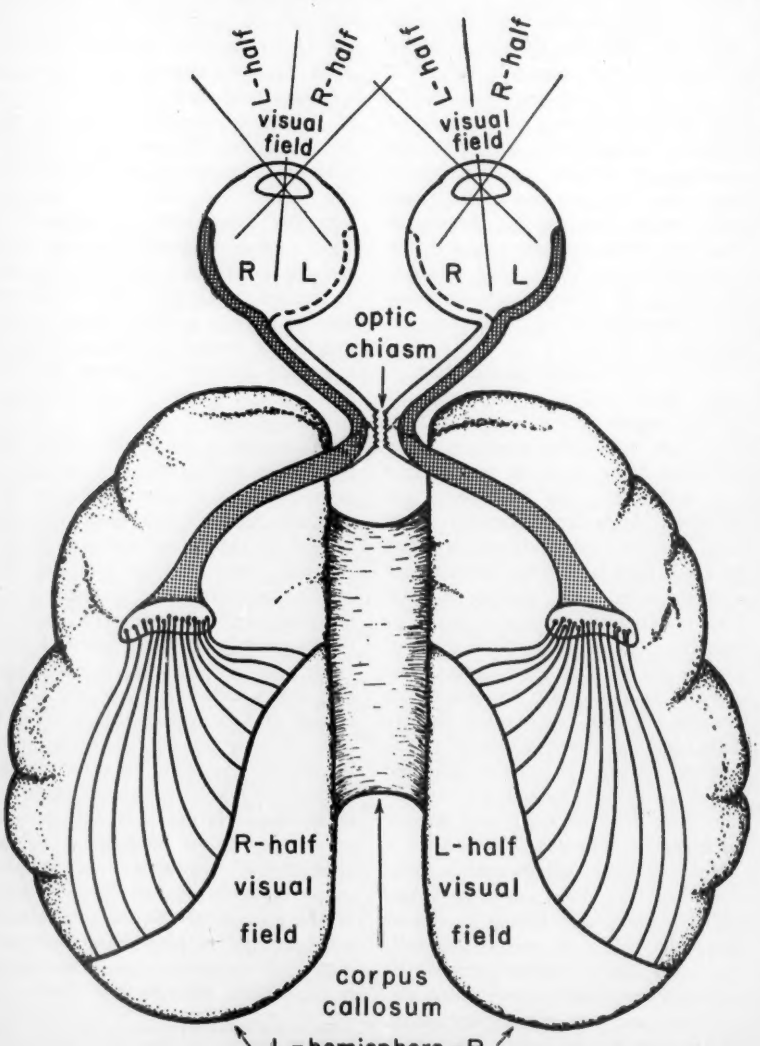
Functions of the Corpus callosum

Although there were indications in the earlier literature on the corpus callosum that this might be the case—indications that now can be picked out, in retrospect—the first convincing demonstration came from the experiments of Ronald Myers on the role of the corpus callosum in interocular transfer in the cat (*1, 2*). In brief, he found that with both the optic chiasm and the corpus callosum sectioned (see Fig. 2), a cat is unable to perform with one eye visual pattern discriminations learned with the other eye. When obliged to use the second eye such a cat behaved normally except that it appeared to have a complete amnesia for the visual training experienced with the first eye. It learned to respond, with the second eye, to a given stimulus in a manner exactly the reverse of that in which it had been trained to respond with the first eye, and learned the two responses with equal ease.

In controls in which only the chiasm is cut and the callosum is left intact, discriminations learned with the first eye are readily performed with the second. If the corpus callosum is not cut until after training with the first eye is completed, the learning again transfers, and thereafter the learned discrimination can be performed with either eye (*2*). If, after training with the corpus callosum intact, the cortex on the directly trained side is ablated, one still gets transfer of the habit to the second eye (*3*). In other words, the corpus callosum is shown to be instrumental in laying down a second set of memory traces, or engrams, in the contralateral hemisphere—a mirror-image duplicate or weak carbon copy of the engram on the directly trained side, perhaps, to judge from the symmetry of reciprocal cross-connections in the callosal fiber pattern. These ex-

The author is Hixon professor of psychobiology, California Institute of Technology, Pasadena.





periments were carried out in apparatus of the type shown in Fig. 3, developed earlier for testing and quantifying refined pattern discrimination in the cat.

Because the memory trace or engram has always been extremely elusive and difficult to pin down or localize by the brain-lesion method, this evidence that it could be confined to one hemisphere by cutting the corpus callosum was not to be accepted without question. Might it merely be, for example, that with chiasm and callosum both sectioned, the hemisphere on the seeing side is more dominant than usual and drains the attention and learning processes off to that side? In partial answer, we find that very large cortical ablations, such as that shown in Fig. 4, that markedly depress pattern vision on the same side, still do not force into the contralateral hemisphere the learning and memory of pattern discriminations performed through the homolateral eye (*4, 5*). Also, when we compared the learning curves for the first and second eye on a statistical basis, there was no evidence that learning with the second eye was benefited by the previous experience with the first (*6*).

In a pedal-pressing apparatus, developed largely by Stamm (see Fig. 5), we were able to demonstrate that the same kind of functional independence prevails in the separated hemispheres with respect to somesthetic learning and memory involving touch and pressure on the surface of the forepaw (*7*). Not only sensory discriminations of the kind illustrated in Fig. 5 but also the simple motor patterns acquired in learning to operate the pedals smoothly were transferred to the second paw in normal cats but were not transferred in the callosum-sectioned subjects. Again, statistical comparison of the learning curves for the first and second paws indicated complete absence of any transfer of learning from one to the other hemisphere. Learning a reverse response with the second paw proceeded as easily in these subjects as relearning the original response. Further, the learning of reversed or diametrically opposed discriminations by right and left paws was carried out

Fig. 1 (top). Midline structures divided in surgical bisection of mammalian brain. Fig. 2 (bottom). Effect of sectioning crossed fibers in optic chiasm. Half-field overlap from contralateral eye is eliminated; this restricts visual inflow to the homolateral hemisphere.

simultaneously by the split-brain cats when right and left limbs were alternated every few trials during the training, and still with no apparent interference between the conflicting habits (*8*).

The findings with respect to visual learning and memory have been confirmed in the main for the monkey as well, with extension to discrimination of colored and three-dimensional objects (*9–11*). Because the monkey is much less inclined than the cat to be cooperative about wearing an eye patch, a training box was devised like that sketched roughly in Fig. 6, which has one viewing slot accessible only to the left eye and another accessible only to the right eye, each of which can be opened or closed from trial to trial. A sliding arm panel controls the use of the arms and permits the pairing of either eye with either hand from trial to trial.

This has the advantage over the use of an eye patch for monocular testing and training in that one can easily switch from one eye to the other, giving a few trials to the right eye, then a few to the left, and so on. If this is done while the monkey is learning reversed discriminations with the separate eyes, one can show that while one hemisphere is in the process of learning, for example, to avoid crosses and select circles, the other hemisphere can be learning to do exactly the reverse. The learning curves for the two conflicting habits then rise concurrently in parallel in the two hemispheres with no apparent interference. The normal brain does not of course operate in this way—nor does that of controls with only the optic chiasm cut, nor even that of controls with section of chiasm plus anterior commissure plus the anterior half of the corpus callosum.

Without going further into studies dealing with the properties of the callosum, it may be said that several different functions for this structure are now recognized. First, and perhaps most significant, is that of the laying down of duplicate engrams in the contralateral hemisphere, as outlined above. In this the callosum serves to keep each hemisphere up to date on what's new in the other; it tends to equate the two hemispheres for those new organizational properties added through learning. It can also be shown that where learning has been deliberately restricted by experimental procedure to one hemisphere, with the corpus callosum left intact, the callosum can then be utilized by the uneducated hemisphere to tap the engram systems of the trained side (*3*). The callosum also aids in certain types of bilateral sensory-sensory and sensory-motor integration, as for example in visual use of either hand across the vertical midline of the visual field (*8, 12, 13*). A general excitatory tonic effect can also be demonstrated in the unilateral blindness of one or two weeks' duration produced by section of the callosum in animals with a surgically isolated visual cortex (*8*). Qualifications of the above properties and special problems relate to the development of language and its lateralized dominance in the human brain, about which little can be said at present. With further analysis it may prove that some of these diverse functions derive from basically the same mechanism.

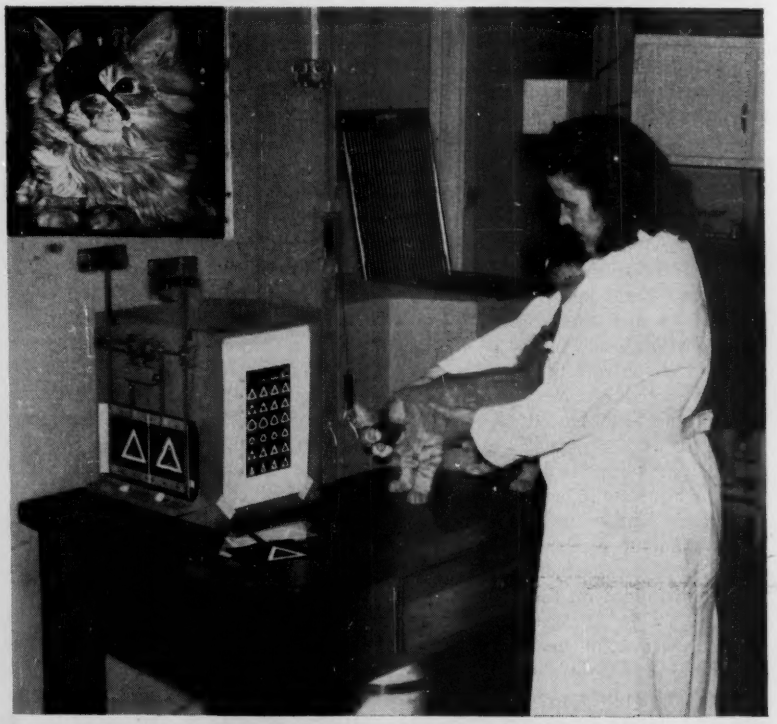


Fig. 3. Visual training apparatus. The cat, placed in the darkened box, obtains a food reward by pushing on the correct one of two translucent patterns interchanged in doors at the end of the box. Inset shows enlargement of the cat wearing the eye patch devised by Myers. Made of rubber, it is simply turned inside out to cover the other eye.

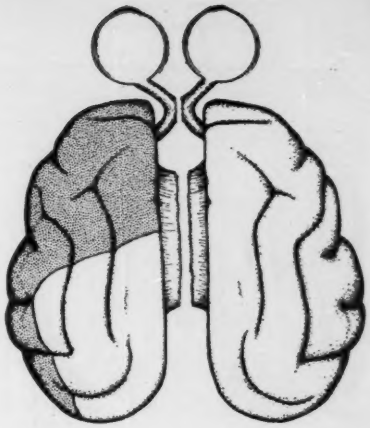


Fig. 4. Extent of the extravisual cortex ablated from the seeing hemisphere of a split-brain cat (*4*).

Simultaneous Learning Processes

After it had been found that the split-brain monkey is able to learn reverse discriminations concurrently with the separated hemispheres (*10, 11*), the question arose as to whether the two hemispheres could learn their reverse tasks simultaneously. Instead of alternating between right and left eye during the training, what happens if

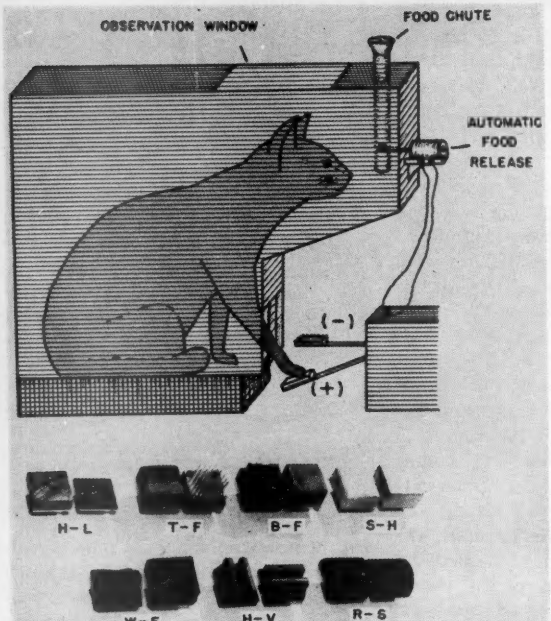


Fig. 5. Simplified diagram of the pedal-pressing apparatus for training in tactile discrimination. Pairs of interchangeable pedal mountings are shown at bottom (*7*, *15*).

both eyes are left open and each trial feeds conflicting information back through the two eyes at the same time? In other words, does the split-brain animal, in order to learn, have to attend to the information entering one hemisphere at a time? Or does it have two separate attention processes, both able to operate simultaneously, handling the diverse sets of information and filing them in two separate memory systems capable of independent recall?

The question has been answered in part by Trevarthen (*13*), with an apparatus incorporating polarized light filters to make the two stimulus objects to be discriminated appear simultaneously different to the two eyes. As explained in Fig. 7, what looks to one hemisphere, for example, to be a circle on the left and a cross on the right is made to look the reverse to the other hemisphere. While one hemisphere observes that the pushing of circles but not crosses is rewarded, the other eye and brain discover, by the same process, the converse—that is, that the pushing of crosses is rewarded and not circles. Any kind of projectable two-dimensional figure, design, or picture may be used, with or without color. Learning is allowed to proceed with both eyes open until the learning curve reaches the 90-percent level. The eyes are then tested individually to find out if the learning has occurred in one or in both hemispheres, and to what degree.

Although the results vary, as expected, Trevarthen finds that during the time required for the dominant hemisphere to learn its problem, the other also, in the majority of cases, has been learning its own reverse problem in part or in full. In some instances, both hemispheres fully learn their separate problems simultaneously. In other words, in approximately the length of time and number of trials required by an ordinary-brained monkey to learn one discrimination problem, these altered, twin-brain monkeys are able to master two such problems. This raises some questions with regard to learning theory and the role in learning of attention, motivation, mental and motor set, and the like. Are all such components of the learning mechanism doubled in these brains, or are some perhaps bifurcate in form, with a common brain-stem element and qualitatively different cerebral prongs? The implications are intriguing and suggest further variations on the initial experiment.

The question of mental conflict is frequently raised in this connection: What happens when one hemisphere has been trained to do one thing and the other trained to do just the opposite, and the animal is given a free choice to perform either or both? With two separate volitional systems inside the same skull, each wanting its own way and each, by training, wanting the opposite of the other, does each of these thinking entities try to decide for itself?

When such a test is run—by rotating one of the eye filters 90° for example—one sees little evidence of internal conflict, apart from, perhaps, a little hesitance (*14*). By and large, the monkey starts selecting circles consistently or crosses consistently, and it may shift from one to a series of the other, thereby telling us which hemisphere is being used at the moment. These shifts are controllable in part by forcing the use of one or the other hand, which then tends to bring into play the contralateral hemisphere, though this latter correlation is not fixed or rigorous. Apparently when a hemisphere once gains the ascendancy, the lower centers tend to throw their full allegiance to this side. Anything coming down from the other hemisphere that is incompatible or out of line with the going activity of the dominant control is automatically inhibited. This is just another example of the general rule that the patterning of excitation in the central nervous system is an either-or kind of thing. Either one unified pattern or another prevails; seldom is there a confused mixture.

The split-brain cat or monkey is thus in many respects an animal with two separate brains that may be used either together or in alternation. With all pairs of major suprasegmental controls bisected, there is no way for the higher-level integration of one hemisphere to reach and influence that of the other except indirectly through the lower brain stem outflow (Fig. 8). By the time the data processing has reached this stage it already is in such form that any recurrent feedback into the opposite hemisphere carries little of the original content.

Bilateral Hegemony

Each of the twin half brains with its full complement of control centers has much bilateral hegemony over the brain stem and spinal cord and is thus capable, to a large extent, of taking over and governing the total behavior of the body. The cat especially, but also the monkey and even man, with

one hemisphere gone manages to get along fairly well, and most central nervous functions are retained. With both hemispheres present, in the split condition, even though one be strongly dominant or in exclusive control of the going higher-level activities, the other presumably continues to contribute much to generalized, background function. Under most ordinary conditions the higher activities also are bound to have much in common. Only in special training and testing circumstances does the double mental control become apparent. The simultaneous use of the two divided hemispheres presents little problem so long as there is unity in the lower centers. Given lower-level harmony, it doesn't matter, as seen above, whether the higher centers function similarly or in direct contradiction.

There is much yet to be learned in following up studies, like the foregoing, that deal directly with the functional properties of the bisected brain, split to different levels and with various incomplete patterns and combinations of commissurotomy. The split brain may also be used to advantage as a basic preparation for attacking other kinds of questions not directly related to problems of commissure function. With the brain bisected, it becomes possible to direct one's ablations, tests, and other analytic procedures to a single one of the hemispheres, leaving the "spare" hemisphere for the use of the animal. In addition to the obvious benefit to the animal over the usual bilateral invasion, there are a number of significant technical advantages in working on the half brain instead of the whole brain. It is important to remember in this connection that the half brain is, in a sense, pretty much a whole brain in that it contains a complete set of cerebral integrating centers and all their interrelations. That is, practically the entire pattern and most of the problems of cerebral organization are there for the unraveling within the half brain.

Advantages for Experimentation

One obvious advantage of the split-brain preparation lies in the factor of built-in controls within the spare hemisphere, controls for all sorts of experiments ranging from short-term studies on innate organization to studies on the long-term effects of early experience on adult behavior. These controls are not only of the homozygous, identical-twin, type but are equated also for almost all experientially derived organization implanted up to the time of splitting. The control hemisphere is fairly well balanced for additions thereafter, also, except for performances that have been deliberately lateralized. These contralateral cerebral controls

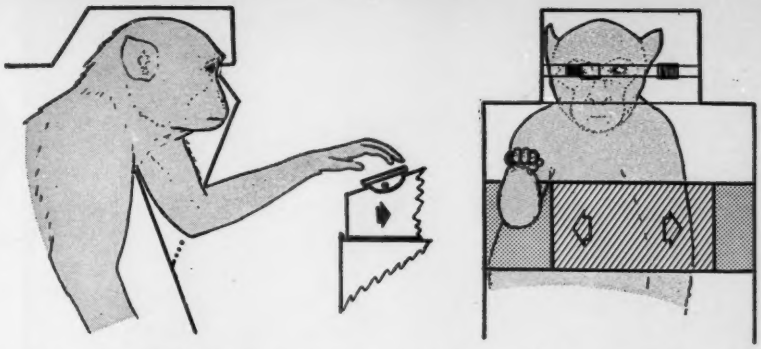


Fig. 6. Profile and front-view outline sketches of a training box for controlling eye-use and eye-hand associations in a monkey.

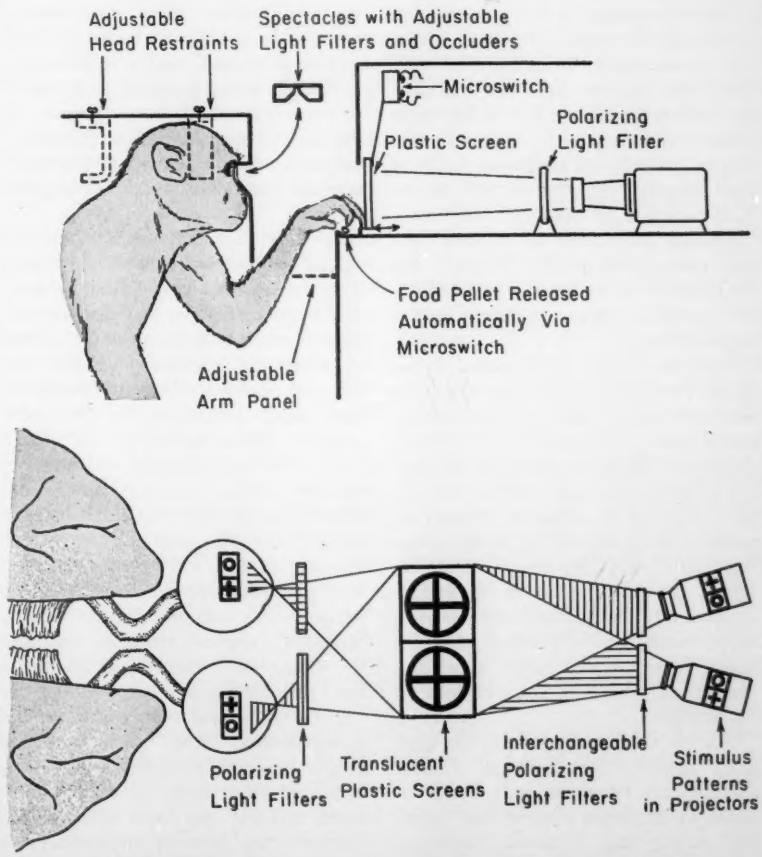
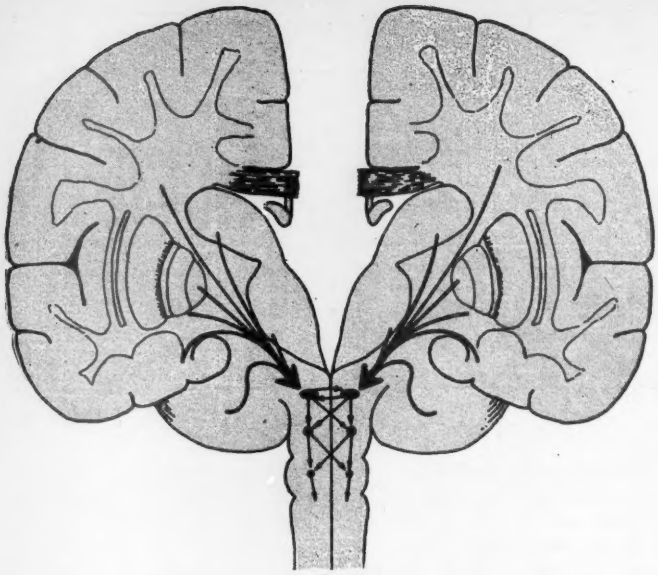


Fig. 7. Profile and schematic diagram of apparatus for testing perceptual conflict in a split-brain monkey (*13*).



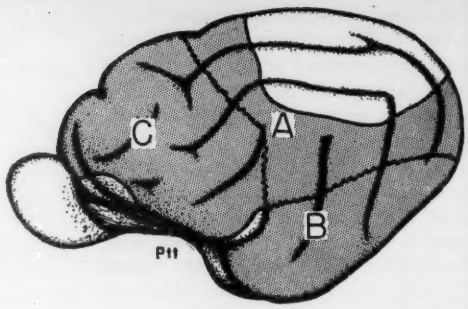


Fig. 8 (left). Schematic diagram to aid in visualizing hegemony of the hemispheres of the split brain over lower centers. Fig. 9 (above). Surgical isolation of central visual cortex in test hemisphere: extravisual cortex removed in three successive operations, *A*, *B*, and *C*, to determine separate functional contributions (*4*).

are thus of a quality almost impossible to obtain by using different animals.

More important is the possibility of extending the surgical analysis within the experimental hemisphere of the split brain far beyond what was possible when the lesions had to be made bilaterally. It has been a long-standing rule in brain-lesion studies of learning and memory that the cortical lesions must be made on both sides to obtain a genuine loss. Unilateral removals are not critical, ordinarily because the functions involved can be handled by the remaining integrating center on the opposite side.

With the split-brain approach it becomes possible to investigate structures like the caudate nucleus, the primary motor cortex, and others, the bilateral ablation of which produces incapacitating or other secondary undesirable effects that act to obscure or confuse possible contributions in other activities. Each brain center tends to be involved in a whole spectrum of different functions. In many cases only the basic impairments can be inferred after bilateral removals, the others being hidden or untestable in the presence of the former.

For the same reasons, with the split-brain approach much larger cortical ablations can be made, even to the extreme of removing most of the cortex and saving only isolated functional remnants—the converse of the usual procedure. We isolated the visual cortex of the cat in this way (see Fig. 9) and found that the primary visual cortex, without aid from other cortical areas, is incapable of sustaining visual functions beyond a bare minimum. A next step is to go back and restore in other animals different portions of the cortex removed in these subjects to determine the respective contributions of each portion to visual learning and memory.

A very different result followed similar surgical isolation of the frontal cortex that includes the somatic sensory and motor areas. In this case the isolated remnant was found to be capable of mediating excellent learning and memory of new somesthetic discrimination habits performed in the pedal-pressing apparatus shown in Fig. 5 (*15*). The ever-elusive engrams or memory traces for these new habits would seem to have been at least cornered within the local cortical area illustrated in Fig. 10. It should be possible to further localize the engram by paring away additional parts of the remaining cortical remnant and also by adding deep electrolytic lesions to test the functional contributions of various subcortical centers that remain undegenerated. This somatic island preparation thus furnishes a promising means of determining the critical minimum cerebral apparatus essential for discrimination learning and memory in the mammalian brain. With one hemisphere preserved intact to maintain background and lower-level activity, it becomes feasible, in the experimental hemisphere, to undertake almost complete surgical dissection and analysis as far as function is concerned. About the only limitations that remain are those imposed by surgical technique, particularly that relating to the preservation of circulation.

To further assure, in these studies of somesthetic discrimination habits, that the habits were not being learned and mediated by the contralateral somatic cortex, a complementary removal of the corresponding area was made on the opposite side. The feasibility of thus adding complementary lesion patterns in the intact hemisphere of the split brain offers further possibilities for the analysis of functional relationships—possibilities not available, of course, where the removals have to be made bilaterally.

There are other promising angles in investigations of this "somatic island preparation." For example, it is possible to test the proven pedal-pressing learning capacity of this cortical area with visual or auditory instead of tactile stimuli—in other words, to answer the questions: Could such a cat learn to press a pedal that activates the correct one of two different tone patterns, or the correct one of two different visual patterns? If not, could it then do so if an isolated patch of auditory or visual cortex were left on the same side as the somatic island? If not,

again, what kind of inter- and intrahemispheric bridges and connections are needed to satisfy the learning and memory requirements?

Visuomotor Coordination

Figure 11 illustrates a type of complementary lesion preparation we have been using, with a number of variations, to determine the neural pathways used in visuomotor coordination. The experimental question here was: Can visual information that is processed in one hemisphere serve as a guide for limb responses for which the cortical centers lie in the opposite hemisphere and are surgically separated from the visual inflow?

Cats, so prepared, and also monkeys that have undergone similar surgery, are able to use vision to direct the homolateral forelimb and to aim it with near-normal accuracy at both stationary and moving objects (*16*). Presumably the speed and accuracy might be shown to be somewhat below that in control animals using the other limb, governed from the same hemisphere, if sufficiently delicate tests were available. However, the performance is still there and not markedly impaired. Where the visuomotor guidance depends on unilaterally learned visual discriminations in split-brain cats and monkeys, either forelimb can still be used without difficulty both during learning and in retention tests (*11, 17*). The neural pathways for these volitional eye-hand coordinations have yet to be determined.

Somewhat in contradiction to the observations that the split-brain monkey or cat readily pairs either eye with either "hand" is a more recent report (*12*) that visuomotor coordination is markedly disrupted under these conditions, to the extent even that prolonged relearning is required, much like that demanded after unilateral removal of the precentral motor cortex. This observation, though yet unexplained, may be a reflection of particular testing conditions that unduly facilitate the use of the visuomotor system for the contralateral limb.

In any case, the expected preference for the favored arm—that is, for the arm governed from the hemisphere that receives the visual inflow—is found and can be demonstrated in more delicate testing conditions such as those obtainable in the training apparatus described above (Figs. 6 and 7), where the monkey is able to use either arm with either eye. This arm preference is easily overcome, however, in a matter of hours in most cases, and may be lacking from the start in animals in which the homolateral arm is strongly dominant, either naturally or as a result of experience in a given testing situation. Trevarthen (*13*) describes distinct differences in the learning curves obtained in pairing the homolateral and contralateral arms with a given eye that indicate basic differences in the neural mechanisms for the two combinations. With the homolateral arm, the reaction time tends to be longer, and the learning slower and more erratic and unstable. The effect is enhanced in monkeys with deeper splits that include the cerebellum.

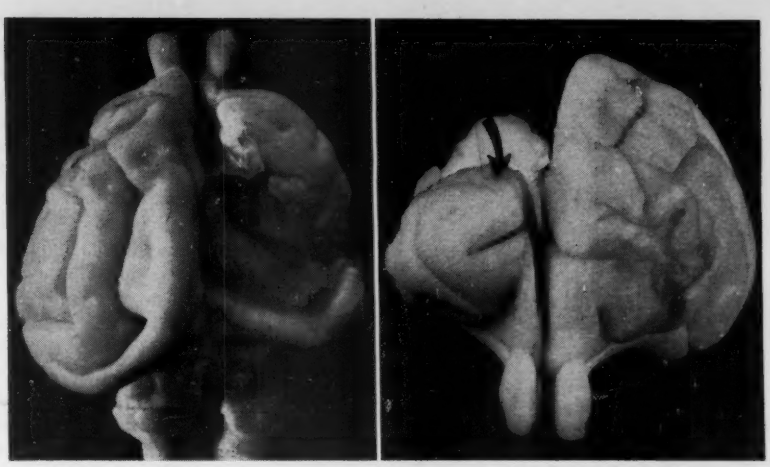


Fig. 10. Top and front views of somatic island preparation with a small complementary ablation in the control hemisphere. Engrams for tactile-discrimination learning appear to be localized within the cortical remnant of the right hemisphere (*15*).

Surgical preparations similar to that illustrated in Fig. 11 have been used for study of the old and still puzzling problem of the neural pathways involved in the conditioned response. In this case a visual signal is used as the conditioning stimulus to establish a conditioned flexion of the forelimb, the cortical centers for which have been left in the opposite hemisphere. Efforts are now under way to eliminate successively the remaining undegenerated thalamic, midbrain, and other subcortical centers until the critical associations and pathways for the conditioned reflex are delineated (*18*). At the present stage of this program the conditioned forelimb flexion in response to a flashing light signal has been found to survive the following: section of left optic tract; ablation of left occipital (visual) cortex; near-total removal of neocortex from the right hemisphere; midline section of corpus callosum plus the anterior, posterior, hippocampal, and habenular commissures; and midline section of the massa intermedia and the quadrigeminal plate—produced stepwise in the same animal.

Another application of the split-brain approach is indicated in Fig. 12. The behavior under analysis in this case is a kind of sensory-sensory association in which the monkey is trained to perform a discrimination problem that requires in each trial an association of visual plus tactile stimuli. By controlling the hand and the eye used, and thereby the cortical receptor centers involved, it is possible to test intra- and interhemispheric integration with and without different parts of the corpus callosum and then with various types of separating cuts and ablations, to analyze the kind of neural mechanism and associations that mediate this type of perceptual integration.

It was something of a surprise to find that the split-brain monkey was still able to perform the visuotactile integration with the tactile stimuli presumably restricted to the hemisphere opposite that of the visual inflow. In addition to making the animal use the proper hand, the somesthetic cortex was ablated on the side of the visual inflow. We first used color-plus-weight (largely proprioceptive) discriminations (*10*,

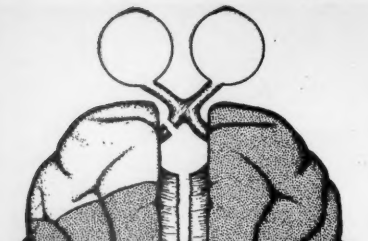


Fig. 11. Basic complementary lesion pattern used with variations for analyzing conditioned response learning and visuomotor coordination.

11) and are now repeating the study with black-and-white patterns and cutaneous rough-smooth stimuli. In the latter study the monkey is required to pull the rougher of two levers when they are presented behind one visual pattern, and the smoother of the two when they are similarly presented in back of another visual pattern, the two visual patterns being black and white and equated for brightness. This latter performance ability is retained even after additional midline sections have been made (see Fig. 12) that include the habenular and posterior commissures, the massa intermedia, and the quadrigeminal plate, in addition to the corpus callosum and the anterior and hippocampal commissures. The removal of the arm area of the tactile cortex on the side of the visual input (Fig. 12) abolishes performance with the affected hand for several weeks but fails to disrupt performance with the hand governed from the opposite hemisphere. This puzzling result is under further investigation, along with similar cross-integration effects that have appeared recently in studies of visuo-visual conditional discriminations. The surgical analysis promises to be easier in the latter because the input pathways for vision are less diffuse and more easily confined than are those for touch.

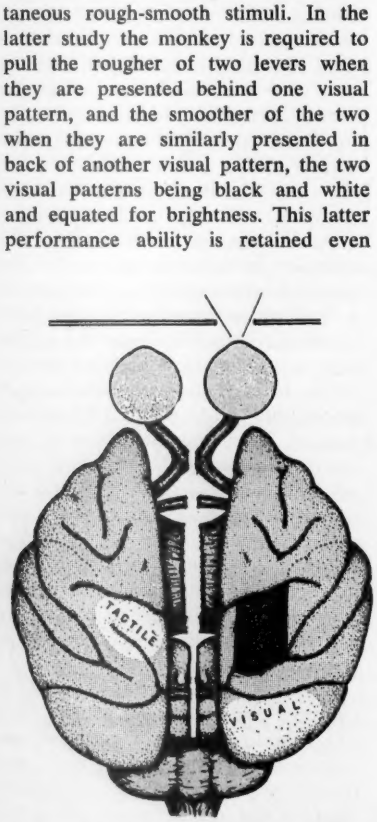


Fig. 12 Stylized representation of monkey-brain hemispheres and underlying midline structures, split through the quadrigeminal plate to the level of the trochlear nerve (*11*), as prepared for a study of visuotactile integration.

Fig. 13. A split brain, as prepared for a study of prefrontal lobe syndrome (*18*).

Application to Old Problems

A simple application of the split-brain approach to an old problem is illustrated in Fig. 13. It has been known for many years that bilateral but not unilateral removal of the prefrontal lobes impairs the performance of delayed response in the rhesus monkey. Whether this impairment is indicative of a genuine function of this portion of the brain has been uncertain, in part because the bilateral removals tend to produce also hypermotility and distractibility. It has been found that the impairment, unaccompanied by hyperactivity and distractibility is produced by unilateral lesion in the split-brain animal (*5, 19*). The unilateral approach thus yields new information regarding the nature of the syndrome and its intrahemispheric involvement; also it permits further analysis through partial removals of the corpus callosum in combination with complementary lesion patterns—procedures not feasible with bilateral ablation.

The split-brain approach has been applied also to the classic Klüver-Bucy temporal lobe syndrome and some of its subsequent fractionations (*20*). Bilateral ablation of the temporal lobes in monkeys produces impairments in visual perception, a change in temperament in the direction of tameness, hypersexuality, and certain oral and "stimulus bound" tendencies. Observations to date show that most features of the syndrome are demonstrable after unilateral ablation in split preparations (*21–23*), and the results bring additional insight regarding the underlying neural mechanism. Similarly, a great many of the older brain-lesion studies can be repeated to advantage in the bisected brain, with a gain in information and the possibility of advancing the analysis.

Transfer across the Midplane

With the growing application of brain bisection to a wide variety of problems, it becomes increasingly important to have background information about the functional properties of the split brain in all its various forms—that is, with the midline sections carried to different levels and with different patterns of commissurotomy and ablation. Particularly critical are questions relating to the leakage or transfer of various functions across the midplane. In this connection, observations bearing on the intermanual transfer of learning (*10, 24*) have not been entirely consistent in primates. In our own experience, section of the cerebral commissures may lead to failure of intermanual transfer, but this is not true in all cases nor under all conditions. We have seen intermanual transfer of tactile discriminations in chiasm-callosum-sectioned monkeys that were already experienced in using either hand with either eye and had been trained with pairs of objects that

were left in sight because they were distinguishable only by touch, not by vision, the one being harder or heavier or looser than its mate, and this being discernible only upon palpation. Also, we find that an ablation of the somatosensory arm cortex roughly like that shown in Fig. 12 will induce transfer in split-brain monkeys that had failed to exhibit transfer prior to the cortical ablation (*25*). The interpretation of this latter finding is complicated at present by the fact that when the monkeys are trained to reverse the discrimination response with the second hand, this reversal training consistently fails to transfer back again to the first hand.

Certain types of visual discrimination learning also have been found to be subject to interocular transfer after section of all forebrain commissures plus the optic chiasm. This has been shown for obvious brightness discriminations in cats, whereas the more difficult near-threshold discriminations fail to transfer (*26*). Interocular transfer of easy color and brightness discriminations and possibility of very simple pattern discriminations occurs similarly in the monkey, according to Trevarthen (*14*). All of these transferable aspects of visual learning may be elements of visual inflow or learning that cross at the midbrain level. Extension of the tests for color, brightness, and simple pattern to several monkeys having deeper midline sections that include the posterior commissure and rostral half of the quadrigeminal plate (see Fig. 1), plus the cerebellum in one case, show so far a lack of memory transfer for all except simple intensity discriminations.

Evidence is still sketchy regarding the extent to which the divided hemispheres can function independently with respect to emotion. Incidental observations made in the course of training and testing suggest that milder aspects of emotional attitude and temperament, like stubbornness and sulkiness, can be confined to one side (*10, 11*). By employing deliberate procedures for inducing experimental neurosis, it might thus be possible to make one of the separated hemispheres "neurotic" and leave the other normal. The "taming effect" of unilateral deep temporal lobe ablation is much enhanced and lateralized in the split-brain monkey, according to Downer (*21*) and others (*23*). Such animals act normally fearful, or ferocious when using the eye connected to the intact hemisphere, but promptly become more tame, placid, and generally less "touchy" when the lesion hemisphere is made dominant by switching the visual occluder to the other eye. The placement of complementary lesions in right and left hemispheres that produce opposed emotional effects has yet to be explored.

Experimental Possibilities

By the use of positive and negative reinforcement through implanted electrodes under remote control, the development of different or opposed preferences in right and left brain could presumably be extended to animate objects and social relationships, with some interesting consequences. The so-called *encephale isolée* and *cerveau isolé* preparations of Bremer and others (*27*) have found considerable use in physiology, and it should not be too difficult to go further and, by adding hemisections of the brain stem to the midline surgery, prepare isolated half brains of different forms and with different kinds and degrees of isolation that would offer significant advantages over the separated whole brain. The isolated half brain could be studied over a long period in the animal in vivo, in the brain's natural habitat, under normal biochemical conditions, and after recovery from the prolonged depression of surgical cerebral shock. To what extent might such long-isolated (or partially isolated) half brains regain wake-sleep states and consciousness and be capable of learning, remembering, feeling emotion, and the like? Where behavioral output is excluded, electrophysiological indications of some of these capabilities could be obtained with implanted electrodes and conditioning techniques.

By combining various ablations and transections like those described above with more localized lesions produced in subcortical nuclei with the stereotaxic apparatus, it is possible today, with methods now available, to attain a fairly extensive surgical dissection of the mammalian brain and to set up a large variety of combinations and permutations of cerebral centers and connecting pathways in animal subjects for long-term functional testing and analysis. Combine with this the analytic potentialities of the chronically implanted electrode for recording, stimulating, and self-stimulating in free-moving, unanesthetized animals, plus the new automated training and programming techniques, along with other technological advances, and those of us working in brain research find ourselves today, as never before, surrounded by seemingly endless possibilities just waiting to be explored (*28*).

References and Notes

1. R. E. Myers, *J. Comp. and Physiol. Psychol.* **48**, 470 (1955); ———, *Brain* **79**, 358 (1956); ——— and R. W. Sperry, *Anat. Record* **115**, 351 (1953).
2. R. E. Myers, "CIOMS Conference on Brain Mechanisms and Learning," in press.
3. ——— and R. W. Sperry, *A.M.A. Arch. Neurol. Psychiat.* **80**, 298 (1958).
4. R. W. Sperry, R. E. Myers, A. M. Schrier, *Quart. J. Exptl. Psychiat.* **12**, 65 (1960).
5. R. W. Sperry, in *Biological and Biochemical Bases of Behavior*, H. R. Harlow and C. N. Woolsey, Eds. (Univ. of Wisconsin Press, Madison, 1958).
6. R. W. Sperry, J. S. Stamm, N. Miner, *J. Comp. and Physiol. Psychol.* **49**, 529 (1956).
7. J. S. Stamm and R. W. Sperry, *ibid.* **50**, 138 (1957).
8. R. W. Sperry, unpublished.
9. J. L. C. Downer, *Federation Proc.* **17**, 37 (1958).
10. R. W. Sperry, *Anat. Record* **131**, 297 (1958).
11. ———, *Transactions of the Macy Conference on Central Nervous System and Behavior* (1958).
12. J. L. C. Downer, *Brain* **82**, 251 (1959).
13. C. B. Trevarthen, *Am. Psychologist* **15**, 485 (1960).
14. ———, unpublished.
15. R. W. Sperry, *J. Neurophysiol.* **22**, 78 (1959).
16. R. E. Myers, R. W. Sperry, N. Miner, *J. Comp. and Physiol. Psychol.* **48**, 50 (1955).
17. A. M. Schrier and R. W. Sperry, *Science* **129**, 1275 (1959).
18. T. Voneida, unpublished.
19. M. Glickstein, H. Arora, R. W. Sperry, *Physiologist* **3**, 66 (1960).
20. H. Klüver, in *Ciba Foundation Symposium on the Neurological Basis of Behavior* (1958), p. 175.
21. J. L. C Downer, unpublished.
22. G. Ettlinger, *Brain* **82**, 232 (1959); M. Mishkin, *Am. Psychologist* **13**, 414 (1958).
23. J. Steiner and J. S. Bossom, unpublished.
24. F. Ebner and R. E. Myers, *Federation Proc.* **19**, 292 (1960); M. Glickstein and R. W. Sperry, *Am. Psychologist* **14**, 385 (1959); R. E. Myers, *Federation Proc.* **19**, 289 (1960); M. Glickstein and R. W. Sperry, *J. Comp. and Physiol. Psychol.* **53**, 322 (1960).
25. M. Glickstein and R. W. Sperry, *Am. Psychologist* **15**, 485 (1960).
26. T. Meikle, Jr., and J. A. Sechzer, *Science* **132**, 734 (1960); T. Meikle, Jr., *ibid.* **132**, 1496 (1960).
27. F. Bremer, J. Brihaye, G. André-Balisaux, *Arch. suisses neurol. et psychiat.* **78**, 31 (1956).

28. This article is based on a talk given at the Federation Meetings in Chicago for the C. J. Herrick symposium on the physiology of learning, 19 April 1960. A more specialized version is being published in *Federation Proceedings*. Original work discussed has been supported by the National Science Foundation, the National Institutes of Health, and the F. P. Hixon Fund of the California Institute of Technology. Special acknowledgement is made to Harbans Arora, who has performed nearly all our monkey-brain surgery during the past 18 months, and to Lois MacBird who has carried the major responsibility for training, medication, and general laboratory assistance.

Science in the News

The State of the Union Message: Money for Space; Some Implications for Economics and Education

The President's second State of the Union address last week was intended to serve several quite different purposes, two of the most important of which were not even mentioned in the speech.

On the surface, the speech was a description of a number of things the President feels must be done in the interest of the nation's position in the world. The major request was for a 40-percent increase in the space budget, with the understanding that this would be followed by similar increases in future years as part of a determined effort to quickly catch up with and surpass the Russians in manned exploration of space.

The President also proposed a more active civil defense program; an expansion of the Defense Department's ability to fight limited, non-nuclear wars; an expansion of the Disarmament Agency; and a $250-million contingency fund to deal with emergency foreign-aid needs.

In a section probably intended as much for foreign as American listeners the President pointed out "no two nations or situations are exactly alike" and said that the United States would support the economic and social revolution taking place in the underdeveloped countries "regardless of which political or economic route they should choose to freedom": in other words, that American aid would be to support freedom, but not necessarily free enterprise.

Thus far the speech served the two clear purposes of announcing one major new policy (on space) and a number of lesser changes in previously announced plans, and of forcefully restating to the country and the world the Administration's basic views of the country's role in world affairs on the eve of the meeting with Khrushchev. It was important, of course, that the proposals be made before the meeting, lest the new defense measures, the emphasis on civil defense, and other recommendations be interpreted as a perhaps panicky response to something Khrushchev might say during the meetings.

But on another level, the speech was the Administration's roundabout way of announcing the results of the reappraisal of the economy the President had said would be made in the spring, after he had gotten a chance to see how well the economy was coming out of the recession. There was immediate, and almost unanimous, support for the President's recommendations for a much expanded space effort, although there is considerable divergence of views among the Administration's science advisers and within the scientific community generally as to whether this would be the best place to invest so much money. But since few people pretend to be experts on space, the general inclination is to go along with what the President says is necessary. The science of economics is quite another matter. Nearly everyone feels qualified to contradict the experts and the President.

Economics

The great majority of economists, including all those to whom either Nixon or Kennedy looked for advice during the political campaign, agree that the government should spend more—that is, run a deficit—when the economy is slack.

There has been a spirited exchange in recent weeks between Walter Heller, chairman of Kennedy's Council of Economic Advisers, and Arthur Burns, Nixon's principal adviser and chairman of the Council of Economic Advisers during Eisenhower's first term. The debate has not been concerned with whether there should be deficit spending to stimulate the economy, but with how long it will be necessary to stimulate the economy. The Administration's advisers support the longer range stimulation, and consequently have argued that programs can be initiated now whose economic impact will not be felt until late 1962 and beyond, since stimulation, in their view, will still be needed then. Burns urges caution on these long-range programs, warning that the spending will probably come at a time when stimulation is unwise and inflationary.

But the debate in Congress and in the nation is conducted on a quite different level. Eisenhower supporters point with pride to the way, as soon as the economy began to come out of the 1958 recession, his Administration got the budget back from a $12 billion deficit in fiscal 1959 to a $1 billion surplus in fiscal 1960. But both Burns and Heller, along with the great majority of their fellow economists, agree that this abrupt shift back to a surplus before the economy was really on its feet again was a major cause of the 1960 recession.

Given the lack of general understanding of even the basis of the debate among professional economists, Kennedy avoided the economic issue and portrayed the extra spending he was recommending as a sacrifice the country ought to be willing to make in the interests of national security. This may turn out to be true in the future, after full economic recovery has been achieved, but at the moment it is quite the opposite of the Administration view, which does not see the extra spending as a sacrifice but as a way to make use of some of the potential in the economy that would otherwise be wasted. In this view, spending would only involve sacrifices if the economy were at a peak, in which case it would be necessary to raise taxes to put through the program without inflation.

This approach, of justifying the new spending in ways that can be easily understood as spending in the interests of national security, has its effects on the kind of programs the President recommends. If the President had complete control of Congress it is doubtful, if not unlikely, that quite so much emphasis would be put on space. In February, the Administration cut out $200 million of the nearly $400 million the Space Agency asked for beyond the Eisenhower budget. When the Russians orbited a man in space, Administration

spokesmen pointed out that everyone knew the Russians were going to beat us on this project, and that it was not necessary to step up the space program in response to this long-expected setback. Now the President has asked for a $600 million increase for the coming year.

The decision is not explainable solely in terms of economic policy, but one of the factors that caused the shift was the desire to make use of the unused potential in the economy. There is disagreement in the Administration about whether space is the *best* place the resources might be used, but little disagreement that space is a *good* place they might be used. Space is also an area, like defense, where Congress will probably accept increased spending with little complaint about the budget deficit. As a matter of practical politics, it is more helpful to get Congressional authority to use the now unused resources for a good purpose than to have Congress refuse to allow the resources to be used at all, on the grounds of what the Administration would regard as a misguided interest in economy.

Aid to Education

Aside from economic policy, there was another unstated motive behind the address, particularly behind the President's decision to deliver it in person. Kennedy has sent a score of messages to Congress since his inauguration, several of which have contained more controversial and more expensive proposals than this one. He did not deliver his February appraisal of the economy in person, nor his revision of Eisenhower's budget, which involved 4 times as much money as the current message. But the message, when delivered in person as a second State-of-the-Union address, served a purpose completely aside from revealing some new proposals. It amounted to a pep talk to the country to revive the sense of urgency about getting things done that Kennedy had succeeded in arousing in his first few months in office.

The program most likely to benefit from this pep talk is the controversial aid-to-education bill, which was never mentioned in the message. The message, nevertheless, is bound to help the education bill when it comes to the floor of the House. The emphasis on space helps build support for education, even though the connection between the space age and the need for better education is not specifically mentioned. So does the general support for the President the message was intended to build. The lack of explicit discussion of school aid avoided inviting charges that the speech was "political" or that it was an attempt to put pressure on Congress. The President has merely delivered a call to the nation to rally to his support, and it is a happy coincidence that the school bill, a place where he needs support, happens to be the only controversial matter before Congress at the moment. The measure will get an additional boost from the meeting with Khrushchev this weekend, for it would rarely be more awkward for Congress to hand the President a major defeat than shortly after his return from talking to Khrushchev, which is when the majority apparently plans to bring the bill to the floor of the House.

Senate Passage

Getting the Senate version of the education bill passed, as the Administration wished, before the House had been called upon to act, raised no serious difficulties.

During the first week of the Senate debate Senator Goldwater warned his fellow legislators against assuming the bill could be brought to a vote after only a week's debate. "It may take two weeks," Goldwater said. "It may take three. I am prepared to fight this as long as it takes." The bill finally passed on Thursday of last week, 10 days after the debate began, after the majority leader, Senator Mansfield, made it clear that it would require a filibuster to carry the bill over to this week.

The Senate, which normally meets at noon, met at 11 on Monday, and at 10 on Tuesday. Senator Kuchel, the assistant minority leader, asked Mansfield about his plans. Senator Mansfield, who until now had been able to keep his pledge to try and get the Senators home in time for supper, announced that the Senate would be in session until 10 in the evening. "It is hoped," he said, "we can come in at 9 o'clock tomorrow, Wednesday, and proceed diligently and at length. If consideration of the bill is not finished tomorrow, we might consider meeting at 8 o'clock on Thursday. If it is not finished then, we might meet at 7 o'clock on Friday. If it is not finished then—"

"At dawn on Saturday," volunteered the assistant minority leader.

The meeting at dawn turned out to be unnecessary. By Wednesday night all proposed amendments to the bill had either been voted on or withdrawn. The bill's managers had accepted two minor amendments acceptable to the Administration. All amendments opposed by the Administration had been defeated, in almost every case by margins of 2 to 1 or more. Amendments that would have lessened the chance of the bill's getting through the House were beaten by wider margins. Senator Goldwater's attempt to add aid for private and parochial schools was beaten 65 to 25, and Goldwater's own education program, which he offered as a substitute for the committee bill, was beaten by a margin of 8 to 1.

Goldwater's proposal covered both aid for higher education, as well as school aid, the subject of the debate. For the schools, it offered to property owners a tax cut of about $2 billion a year, which would have cost the federal government nearly 3 times as much as the Administration bill. Senator Goldwater said he saw no need for federal aid to education, but if there was any need, the tax cut would eliminate it by making it easier for state and local governments to raise taxes to take care of the need. Congress could then cut other parts of the President's program to make up for the large revenue loss.

For higher education, Senator Goldwater suggested tax deductions of up to $2000 a year per child for families with children in college. Opponents questioned whether cutting taxes for people who could afford to send their children to college was the most efficient way of helping people who couldn't afford to send their children to college.

Senator Goldwater also proposed a system of national scholarships, up to 1000 a year. These scholarships had an entirely different purpose, Goldwater explained, from the Administration's proposal for 50,000 scholarships a year. The purpose of the program, Goldwater said, was to raise the standards of high school education. His proposal "would have imposed very rigid requirements" for a student to be eligible for a scholarship. "A high school student, before he could qualify . . . would have to write a theme and translate it into a foreign language; would have to translate a theme written in a foreign language into English; . . . he must have completed at least 4 years of English, 4 years of history, 3 years of mathe-

matics, 3 years of a foreign language, 3 years of science, or, in lieu thereof, 3 years of Latin or Greek." Senator Morse, the floor manager of the Administration bill, suggested that although Senator Goldwater opposed federal aid because it might lead to federal control, what he was proposing amounted to federal control without federal aid.

The Senate declined Goldwater's education program by a vote of 79 to 10.

On Thursday night the vote on the passage of the bill turned out to be the narrowest of the entire debate. The margin, though not as wide as had been expected, was a comfortable 49 to 34. Eighteen senators either were not on hand for the final vote, or were paired, but their positions were announced at the roll call. If everyone had voted, the tally would have been 59 for, 41 against.

On the same day the House Education and Labor Committee completed work on its version of the bill. On 18-12 party line votes it defeated Republican attempts to add, over Chairman Powell's objection, a Powell amendment to eliminate money for teachers' salaries, and failing this, to add a loyalty oath for teachers. An attempt to add loans for private and parochial schools was ruled out of order, and its supporters, assured that the Administration would not oppose some form of loan program so long as it was not tied to this bill, did not challenge the ruling.

So the bill will reach its crucial stage, the vote on the floor of the House, in exactly the form and under exactly the conditions the Administration wanted: neither the House committee nor the Senate had encumbered the bill with amendments bringing in either the segregation or parochial school issue; the question of loans for parochial schools would be taken up *after* the vote on the main bill; and to show that the Administration was acting in good faith in its assurance that it would not oppose loans for private schools if offered in a separate bill, the Senate would be in the process of considering such a bill when the school bill reached the floor of the House of Representatives.

The issue still remained in doubt. But, counting on the added impetus of the President's speech and trip, the supporters were more optimistic than they had dared to be at any point until now.—H.M.

Announcements

The Library of Congress has a duplicate stock of back issues of its publications, the **East European Accessions Index** and the **Monthly Index of Russian Accessions**, available for donation to libraries of educational institutions and public bodies in the United States. These publications contain information about the content of new Russian and East European books and articles received by the library and other American research libraries. The library will undertake to fill requests for nearly complete back files insofar as the supply permits. Requests will be filled in order of receipt. (Chief, Exchange and Gift Division, Library of Congress, Washington 25, D.C.)

Meeting Notes

A **shallow water and coastal research** conference, sponsored jointly by the National Science Foundation and the Office of Naval Research, will be held in October at the following regional meeting places:

20–21 October; Chesapeake Bay Institute, Johns Hopkins University, Baltimore, Md.

24–25 October; Oceanographic Institute, Florida State University, Tallahassee.

27–28 October; Allan Hancock Foundation, Universtiy of Southern California, Los Angeles.

The main purpose of the conference is to obtain an inventory of current research and to compile a list of the men actively contributing. Scientists in all disciplines working in the area of the continental terrace and coastal regions are invited to attend the meeting closest to their home organization and to submit a brief review of their research activities and the number of students or junior associates working with them. The reviews will be compiled into a proceedings volume and distributed to all participants after the meetings. In addition to the reviews, oral reports (limited to 10 minutes) of special studies, techniques, and methods will be scheduled. The abstracts of these oral reports will be compiled into regional programs and distributed at the meetings. Five foreign guest scientists will present reviews of their current research at evening sessions, during which time will be provided for general discussion of common problems and informal exchange of ideas and information. The deadline for receipt of reviews (not to exceed 3 pages) is *15 September*. The deadline for 250-word abstracts of oral reports is *1 September*.

The meetings are open to men from academic, government, and industrial organizations. Persons interested in attending should notify the general chairman *before 1 August*. (Donn S. Gorsline, Oceanographic Institute, Florida State University, Tallahassee)

A 3-day symposium on **physics and nondestructive** testing will be held at Argonne National Laboratory 3–5 October. The fundamental physics on which the technology of nondestructive testing is based will be stressed. New methods or the applications of concepts new to nondestructive testing will be included. The program will include papers on linear accelerators and their application, neutron radiography, ultrasonics, infrared physics and other thermal indicators, and radiation damage. (Nondestructive Testing Group, Argonne National Laboratory, Argonne, Ill.)

The 12th **Alaskan Science Conference**, sponsored by the Alaska Division of the AAAS, will be held at the University of Alaska, College, from 28 August to 1 September. The conference will cover the following fields: anthropology, biology, engineering, fisheries, forestry, geology and geography, geophysics, medicine and public health, and social sciences. (David A. Vaughan, Arctic Aeromedical Laboratory, APO 731, Seattle, Wash.)

Grants, Fellowships, and Awards

A $1500 award for an outstanding contribution in **exfoliative cytology** has been established by the Cancer Research Foundation. The award, to be known as the Maurice Goldblatt cytology award, was established to stimulate basic research in cancer detection.

Suggestions and proposals for research in the problem of detection and identification of **underground nuclear explosions** are invited by the Air Force Office of Scientific Research. The new AFOSR program, a part of project Vela-Uniform, covers the following specific areas: development of

reliable means for determining the first motion of *P*-waves; seismic signal analyses, including development of mathematical models relating generating parameters and effects of propagation paths to the recorded signal; development of improved theories and methods for determining the energy level of seismic sources when detected at a distance; basic research in instrument design; studies of data-correlation techniques; studies of geophysical constants of the earth's crust and upper mantle; and studies of the applicability of nonseismic techniques to detection and identification of underground disturbances. The program is being conducted through grants and contracts. (Geophysics Division, AFOSR, Washington 25, D.C.)

The National Aeronautics and Space Administration's office of life science programs is soliciting proposals for ground-based and in-flight experiments in the general area of **space biology**. This area includes the search for extraterrestrial life by remote instrumentation, the study of gravity-sensitive biological systems, and the biological effects of space and planetary environments. A guide for the preparation of proposals will be supplied upon request, and staff members of the office are available, by appointment, for technical discussion. (T. L. K. Smull, Code BG, NASA, 1520 H St. NW, Washington 25, D.C.)

Arthritis. Predoctoral, postdoctoral, and senior investigatorship awards in the fundamental sciences related to arthritis are being offered by the Arthritis and Rheumatism Foundation for work beginning 1 July 1962. The deadline for applications is *31 October 1961*. The awards are intended as fellowships for the training of young men and women for an investigative or teaching career. They are not in the nature of grants-in-aid in support of research projects. They range from $2000–$3000 per year for predoctoral fellowships to $7000–$10,000 per year for senior investigator awards for candidates holding "faculty rank." (Arthritis and Rheumatism Foundation, 10 Columbus Circle, New York 19)

Research grants in the field of the **autonomic nervous system** are now available through the auspices of the Dysautonomia Association. (2 W. 46th St., New York 19)

Scientists in the News

Sir **Russell Brain**, British neurologist, has received the Hughlings Jackson medal of the Royal Society of Medicine, London, for his studies on the nature of speech and its disorders. The award, presented every 3 years, is the highest given by British neurologists.

Selman A. Waksman, director emeritus of Rutgers University's Institute of Microbiology, has been awarded the Trudeau medal by the National Tuberculosis Association.

Sverre Petterssen, professor of meteorology and chairman of the department, and **Julian R. Goldsmith**, professor of geochemistry and associate dean of the physical sciences division, University of Chicago, have been named chairman and associate chairman, respectively, of the university's newly created department of geophysical sciences. The new department is being staffed with faculty members from the departments of astronomy and chemistry and the Enrico Fermi Institute for Nuclear Studies, and with all the present staff of the departments of meteorology and geology.

Lawrence P. Huelsman, associate professor of electrical engineering at the University of Arizona, and **Robert M. Lerner**, assistant group leader in radar techniques at Lincoln Laboratory, Massachusetts Institute of Technology, have been selected to receive awards given by the National Electronics Conference for the best papers presented at its 1960 conference.

The two following appointments were recently made at Georgetown University. **Melvin Blecher**, assistant professor of biochemistry at Albert Einstein College of Medicine, has been named associate professor of biochemistry at the university's schools of medicine and dentistry; **William H. Horner**, associate professor of biochemistry at the university, has been named chairman of the department.

Arthur B. Pardee, professor of biochemistry at the University of California's virus laboratory, in Berkeley, has been appointed director of Princeton University's recently expanded program in the biochemical sciences. Under the new program the departments of chemistry and biology will form an interdepartmental biochemistry committee, of which Pardee will be chairman. The committee will offer a graduate program leading to the degree of doctor of philosophy in biochemistry.

In accordance with an exchange program begun in 1960 between the European Organization for Nuclear Research (CERN) in Geneva, Switzerland, and Soviet nuclear research centers, two French scientists from CERN have arrived in Moscow to participate in research work at the Institute for Theoretical and Experimental Physics, Academy of Sciences of the U.S.S.R. **Philippe Dennery** will work with theoretical research at the institute, and **Robert Meunier** will participate in experimental work being prepared for the 7-Gev synchrophasotron under construction at the institute.

William L. Everitt, dean of engineering at the University of Illinois, has been elected president for 1961 of Associated Midwest Universities.

Howard M. Teeter has received the U.S. Department of Agriculture's superior service award for his "outstanding contributions to science, agriculture and other industries, and the public." Teeter is assistant director of USDA's Northern Utilization Research and Development Division, Peoria, Ill., where he has been employed since 1942.

Two senior chemists at Argonne National Laboratory have been honored by the American Chemical Society for outstanding research work.

Joseph J. Katz received the Nuclear Applications in Chemistry award sponsored by the Nuclear-Chicago Corporation.

Harold H. Strain is the winner of the society's first Chromatography and Electrophoresis award sponsored by Labline, Inc.

Jerome Levy, chief psychologist of the division of mental health, Texas State Department of Health, has been appointed coordinator of the staff development project recently initiated by the Western Interstate Commission for Higher Education.

William B. Bean, professor and head of the department of internal medicine at the State University of Iowa, has been awarded the 1961 Groedel medal of the American College of Cardiology.

Book Reviews

Soviet Marxism and Natural Science, 1917–1932. David Joravsky. Columbia University Press, New York, 1961. xiv + 433 pp. $7.50.

Foreign observers have always been puzzled by many things in Russia and the Soviet Union, but the state of Soviet science and its place in Soviet society are now more puzzling than ever. That a vigorous and imaginative scientific activity flourishes in the Soviet Union is attested by thrilling scientific spectaculars, and even better by incontrovertible technological achievements. Yet, at the same time, a clique of charlatans and careerists palm off prescientific superstition in place of the science of genetics. The temptation is hard to resist to explain these flagrant inconsistencies as the ingredients of one vast and incredibly clever plot, wherein lesser things are sacrificed for the sake of greater aims. Several foreign observers have contended that genetics is incompatible with Marxist philosophy, whereas an oversimplified version of Lamarckism is essential to the communist creed, so essential that it has to be adhered to even at the cost of the destruction of a science which is basic to scientific agriculture and to much else besides.

David Joravsky shows how erroneous are such "magisterial judgments on the basis of insufficient evidence." He chose a harder but in the end safer path, by carefully assembling and critically evaluating a lot of scattered and frequently contradictory data. To do this is more laborious than to editorialize, another temptation which he eschewed. More than a quarter of the book is comprised of footnotes and bibliographies. Many of the sources referred to are accessible only with difficulty, even to those familiar with the Russian language. Joravsky is likely to be the only person in the United States who is acquainted with some of the original documents. The study covers only the first 15 years of the Revolution (1917 to 1932), and the reader is warned that he will not find "a full history of science and higher education in the Soviet Union during the period under review." The book "grew out of an interest in the intellectual history of the Russian Revolution, out of a desire to understand the modern analogues to Marat and Lavoisier in an earlier revolution, or to Calvin and Servetus in another."

"Partyness" versus Objectivity

The first five chapters are devoted to a review of Marxist conceptions of science and of the vagaries of what is known as "partisanship." Nothing makes sense in the history of Soviet philosophy or science unless the principle of partisanship is understood (*partiinost*, rendered, perhaps a bit pedantically, as "partyness"). Lenin, then aged 25, stated the principle mildly: "Materialism includes, so to speak, partisanship, enjoining one in any judgment of an event to take directly and openly the standpoint of a definite social group." Objectivity, dispassionate adherence to facts, willingness to listen to counterarguments are things in which bourgeois scientists and philosophers take pride but which are scorned by their communist counterparts.

Lenin being, Joravsky writes, "Absolutely sure that he and his Party knew the way through the capitalist present of blind necessity to the socialist future of conscious freedom, he believed that his Party enhanced freedom by extending its control wherever refractory forces blocked that way." By 1930, this came to mean (in the words of Mitin): "The philosophy of dialectical materialism is the official point of view, the world view of the Communist Party. Hence it follows that the partisanship of the philosophy of Marxism-Leninism in general, in the conditions of the contemporary stage in particular, signifies and must signify above all its politically efficacious character." In practice this meant "that the resolutions of Party Congresses, the decrees of the Central Committee, and the speeches of Stalin were to be the chief source for the elaboration of dialectical materialist philosophy."

Yet this wise and efficacious philosophy has made some extraordinary zigzags. From 1917 to about the mid-1920's, the philosophy was a mechanistic, reductionistic, and positivistic materialism of a rather crude sort (chapters 6 to 10). Its high priests sat mainly in the Institute for the Study and Propaganda of Natural Science from the Point of View of Dialectical Materialism (Timiriazev Institute, or Timirin for short) and in the Communist Academy in Moscow. Learning this philosophy was compulsory for students, and it was highly recommended to, though not yet demanded of their nonphilosophical professors, a part of the theory being that any good scientist is a practicing materialist, whether he knows it or not. Scientific theories were nevertheless tested by their agreement with the reigning philosophy. Einstein's relativity was on the suspect list, and A. K. Timiriazev, a son of the physiologist, was its chief examiner and prosecutor. In biology Lamarckism, or rather a belief in the heritability of acquired traits, was the preferred view, although genetics was at just that time making rapid strides in the Soviet Union.

Morganism versus Lamarckism

A new tempest started in the Institute of Red Professorship in Moscow, where A. M. Deborin and his students discovered a considerably more sophisticated brand of dialectical materialism. This was to be the only true philosophy, irrefutable because it "is the result of the entire accumulation of human knowledge." Acceptance of this philosophy rapidly became obligatory (chapters 11 to 15). Lamarckism, as a part of mechanistic materialisms, turned suspect, while genetics ("Morganism") agreed with the true faith. How far things went can be seen from this event: in 1928 the geneticist I. I. Agol (himself later executed as a deviationist) demanded not only acceptance of Morganism but also suppression of Lamarckism. The authorities were not ready to go quite so far, but for a time it looked as if genetics was to become a part of the official creed; and, alas, some geneticists were ready to accept the posts of scientific bosses. In 1929 an extraordinary event took place—Deborin's philosophy was officially endorsed by Party authorities and thus became compulsory. The significance of this event was not lost on at

least one Party chief, Miliutin, who stated: "We are adopting—for the first time in history, I dare say—a philosophical resolution. It will be, so to speak, a definite platform in regard to dialectical materialism and a formulation of all the work that will be done in this field."

Soviet Marxism vis-à-vis Natural Science

Deborin's was, however, a Pyrrhic victory (chapters 16 to 19). The year 1929 was the year of the "Great Break," of the start of collectivization of agriculture and of the Five Year Plans. The non-Party scientists and philosophers were to be replaced with all haste by Party men or to be reduced to abject submission. Heads soon began to fall, metaphorically and literally. In 1930 Deborin was declared heretic, together with all those who only a short time before had accepted his officially endorsed true philosophy. His successor, Mitin, declared it was not the academic philosophy but the "masterful application of dialectics that our Party carries out enters into the development of philosophical communist thought as the most important component element." And thus, says Joravsky, "A new phase of the interaction of Soviet Marxism and natural science had begun. . . . now only Stalin and his compliant Central Committee had the requisite world-sweeping vision; lesser philosophers would wait to be told when experience required the Marxist Weltanschauung to be developed further."

Yet not all science was consumed in the revolutionary conflagration. Physics, for example, revived and prospered; much of biology, especially genetics, succumbed. But this story belongs to the period after 1932, and one hopes that Joravsky will extend his study to that period. He hints at an answer in the following lines: "If Lenin had not set the precedent of sharply dividing the scientific from the epistemological in his study of the 'crisis' in physics; if physics had been a less ancient and solidly established science, less rigorous and less prolific in theoretical and practical triumphs; if, accordingly, there had been significant blocks of physicists strongly opposed to each other on basic scientific issues; if, eyeing such a turmoil within physics and anxious for the ideological condition of scientists, the Bolshevik authorities had become involved in a crisis of production so desperate as to nurture feverish dreams of rescue by scientific miracles—then the Soviet Marxist discussions of the twenties and early thirties might well have produced a genuine crisis in physics rather than talk of a crisis on its ideological outskirts. But then, physics would have been biology."

Soviet Science and the Communist Party

Far from having followed consistently some cunning master plan, the relationships between the Communist Party and science in the Soviet Union have involved many capricious turns and have been punctuated by blunders. Joravsky may well write still another book, to discover why science nevertheless developed there as well as it did. I know of nobody better qualified to undertake the task. Having been a witness to some of the events described in this book, I can only admire Joravsky's accuracy and his unbiased presentation. Although any book dealing with Soviet affairs is likely to elicit conflicting opinions, Joravsky's will do so perhaps less than any other. Being a product of sound scholarship, it contains an abundance of documentation which speaks for itself and which absolves the author from inculpation of bias.

THEODOSIUS DOBZHANSKY
Department of Zoology, Columbia University

The Rickettsial Diseases. P. F. Zdrodovskii and H. M. Golinevich. Translated from the Russian by B. Haigh. Pergamon, New York, 1960 (ed. 2, Moscow, 1956). xii + 629 pp. Illus. $17.50.

A valuable characteristic of this book, which makes available in English a great deal of Russian literature and experience, is the authors' willingness to augment published material with discussions of their own investigations. While there are observations with which others may disagree, it is reassuring to know the authors are drawing from firsthand experience based on laboratory work.

The book is divided into general and special sections. The first deals with classification, general characteristics of rickettsiae, the rickettsioses, characteristics of experimental infections in animals, variation, serology, and laboratory methods. The special section consists of a complete presentation of each disease group. Clinical features, epidemiology, immunology, diagnosis, prophylaxis, and treatment are dealt with. Valuable guidance is provided throughout for those working with rickettsiae in the laboratory. The comparison of pathology and other characteristics among the different rickettsioses is very complete. However, this attempt at completeness results in some repetition.

The authors' proposed compromise classification for rickettsiae and the accompanying discussion constitute one of the worst sections in the book. They state: "At the present time we cannot speak of a complete and generally accepted classification of the rickettsiae and rickettsial diseases, since it is far from complete, particularly in foreign countries, in the study of the antigenic structure of the rickettsiae, a knowledge of which is fundamental for their qualitative differentiation and rational subdivision." This would have been a good point at which to drop the subject. However, they continue to use obsolete names and propose ill-considered new ones. This serves only to cast a cloud over our present ignorance.

In contrast to the preceding, the following proposed grouping of rickettsial diseases serves a useful purpose. I: Typhus fever group. II: Tick-borne spotted fever group; (a) New World subgroup; (b) Old World subgroup; (c) Subgroup of gamasid rickettsioses. III: Mite-borne fever group. IV: Pneumotropic group of rickettsioses. V: Paroxysmal group of rickettsioses. VI: Group of rickettsiae and rickettsial diseases of domestic animals. Although North Asian tick rickettsiosis may belong in IIa rather than in IIb and North Australian tick typhus may fall into IIc rather than IIb, the general plan is sound.

There has been a need for this translation and this book, for rickettsial diseases, too often treated as exotic conditions in books on viruses, here achieve full stature. In our own experience, the discussion of allergic diagnosis in Q fever makes a point. During 1959 we applied intradermal tests in epidemiological investigations of Q fever. Some of the observations of Russian workers from 1951 to 1954 recorded here may have been unnecessarily repeated. Although this book may be essential for the experienced worker, it isn't particularly recommended for the beginner because insight is required to evaluate properly some of the Russian claims.

DAVID B. LACKMAN
Rocky Mountain Laboratory, Public Health Service, Hamilton, Montana

An Introduction to the Mathematics of Medicine and Biology. J. G. Defares and I. N. Sneddon. Year Book Medical Publishers, Chicago, Ill., 1960. xii + 663 pp. Illus. $14.

Defares is a physiologist in Leyden where theoretical biology is actively pursued. Sneddon is a well-known Glasgow author of texts on classical mathematical analysis. Their 650-page book gives a polished account of calculus with some 200 pages of applications to physiology. The theory is presented on its own merits, for the most part without apology, and with considerable technical detail and skill. The examples are inclined to be repetitive in principle and are described with less clarity and force than the theory. The printing is excellent.

The book is designed for "the graduate well launched on his chosen career who has ceased to study mathematics many years previously." However, the authors hope "the book will be of use for work in courses on mathematics for biologists." It will compete with a growing number of books for these audiences. There are many indications from influential quarters that the role of mathematics in biological research and teaching is expected to, or "should," expand explosively. At least three conferences on this topic will be held in the United States during this spring and summer. But, curiously enough, the movement seems to come more from the mathematicians than the biologists. Practically no biology department in North America requires any mathematical prerequisites of its graduate students, and it appears that most students don't have much training in mathematics. The physical and social sciences have been much more demanding and articulate in stating their mathematical needs than the biological sciences. Thus, there is no generally agreed upon pattern for books of this kind, and so any opinion on whether such a book attains its aim is likely to depend on the personal experiences and interests of the reader. This, of course, is not to suggest that there should be a fixed mold for books in this or any other area. Furthermore, the range of disciplines encompassed by the biological sciences is so vast and diversified that many types of books are required. Perhaps they will come most naturally, as this one has, by the joint efforts of a biologist working in a specific field of research and a mathematician.

The first two chapters (109 pages), "Algebraic preliminaries" and "Functions of a single variable," review most of the precalculus mathematics covered at school with the exception of algebraic equations. Many examples of the relation of one variable to another are given. Several show how to rescale so that the plot is linear. From my experience, the appreciation of the idea of a function that students gain from this approach is not strong enough to support a discussion of, for example, differential equations. The next three chapters (106 pages), "Limits and derivatives," "The differential calculus," "Integration," cover, without scientific interruption, these topics excellently in the standard way for algebraic and trigonometric functions. Chapter 6 (46 pages) introduces the logarithm as an integral and the exponential as its inverse and gives a number of applications. One interesting example here, entitled "Optimal dosage of drugs," may serve to illustrate my feeling that the treatment of examples is too formal and verbose. The object is to study the build-up of the concentration of a drug in the body, on continued periodic administration, to a maximum level—or that was the object in the original paper abstracted. Here it is also to show students *how* to formulate and solve such a problem. The natural order would seem to be: a rough, intuitive, smooth graph; a saw-tooth graph showing intuitively the effect of elimination of the drug between administrations; a schematic flow diagram labeled with rates of administration and elimination; and then the mathematical formulation, the steady state solution, and then the build-up solution. Instead the differential equation for elimination is given immediately, and three pages of analysis precede the graph. The summing up is diffuse so that in the end very little pedagogic good comes from an excellent example. Chapter 7 (94 pages), "Techniques of integration," begins with 80 well-written pages of technique including a mathematical account of normal, gamma, and beta density functions and a short section on Laplace transforms. The last 20 pages are examples that use only the logarithms and exponentials of the previous chapter. Chapter 8 (73 pages), "Functions of more than one variable," covers briefly partial differentiation, line integrals, a summary of thermodynamic relations, maxima and minima, and double integrals. The only application bearing on the theory concerns the propagation of errors. The book deliberately does not discuss errors statistically so it is inevitable that this classical topic has an air of finality that it does not deserve. Chapter 9 "Differential equations" (81 pages) surveys methods of solving ordinary and partial differential equations while, in chapter 10 (112 pages), "Further applications to medicine and biology," some of these methods are applied to a variety of interesting and instructive problems. Partial differential equations occurring in neurophysiology are not discussed. An appendix describes linear equations and determinants.

The book provides a rapid and reliable introduction to calculus with all the useful results and methods well listed, and with the solution of many differential equations occurring in physiology. Problems (with solutions) are provided.

G. S. WATSON
Department of Mathematics, University of Toronto, Toronto, Canada

Prediction and Optimal Decision. Philosophical issues of a science of values. C. West Churchman. Prentice-Hall, Englewood Cliffs, N.J., 1961. xv + 394 pp. $9.

Space permits but a cursory summary of this book, which is of great importance to practitioners of science. Important it is, for it deals directly with science's ubiquitous question: how can we work toward a science whose recommendations are consistent with social morality? The need for an empirical science of ethical decisions is urgent, but urgency must give way before the recognition that we have little available information about the decision processes science as an institution now employs. In short, a science of science must precede a science of ethical judgments.

Examination of what scientists do shows that value decisions permeate the selection, organization, and analysis of knowledge, yet the way in which these judgments affect their resultant recommendations for action is far from clear. Should the scientist's recommendations be expressed in simple hedonistic terms? In terms of a Kantian calculation of pain-pleasure units? In terms of such more recent concepts as "utility" or maximization of gain? None of these standards for decision fulfills all the requirements of a

"scientific" standard, and none will, seemingly, unless it is a standard rooted in an empirical analysis of actual human behavior.

The preferential choices of humans behaving under conditions of uncertainty can, if other standards of adequate measurement are met, be taken as statements of value. While this is not the only value standard which might be employed, the defensibility of the concept is substantial. Certainly, the careful scrutiny Churchman devotes to this central idea is well worth the significant fraction of the book it occupies.

Equally intricately worked out are the concluding sections of the book, in which Churchman applies the same rigorous empiricism to the value standards of groups and in which he applies value theory to industrial accounting practices and to science itself.

Churchman is explicit: the book is programmatic. This is all to the good, for we may yet hear more of certain subjects (such as his "psychologistics") which seem tantalizing. It is good, too, in that by holding open the theory of science and its values, we may also hear from the theoreticians of differing views who can give this book the serious consideration it deserves.

DONALD G. LIVINGSTON
Laboratory of Psychological Studies, Stevens Institute of Technology

Das Leben des Szelider Sees. Limnologische Studien an Einem Natriumkarbonat-Chloridhaltigen See des Ungarischen Alfold. Ernö Donászy. Akademiai Kiadó, Budapest, Hungary, 1959. 425 pp. Illus. Plates. + soil map (in color).

This book is a well-organized and well-documented inventory of the limnological characteristics of a shallow Hungarian lake whose waters contain unusually large quantities of sodium carbonate and sodium chloride. Incorporated are contributions by a number of collaborators working in various Hungarian laboratories. The chemical constituents of the lake are recorded in detailed figures and tables. In addition, there are drawings of diatoms and algae and quantitative data on phytoplankton, large aquatic plants, entomostraca, and rotifers.

ARTHUR D. HASLER
Department of Zoology, University of Wisconsin

New Books

Mathematics, Physical Sciences, and Engineering

Advances in Chemical Physics. vol. 3. I. Prigogine, Ed. Interscience, New York, 1961. 381 pp. Illus. $11.50.

Advances in Electronics and Electron Physics. vol. 13. L. Marton, Ed. Academic Press, New York, 1961. 464 pp. Illus. $13.50.

Algebra. An elementary text-book for the higher classes of secondary schools and for colleges. pts. 1 and 2. G. Chrystal. 595 pp; 640 pp. Chelsea, New York, ed. 6, 1959. Illus. $2.95 each.

Aristotle's Physics. Newly translated. Richard Hope. Univ. of Nebraska Press, Lincoln, 1961. 254 pp. $6.

Atomic Physics Today. Otto R. Frisch. Basic Books, New York, 1961. 562 pp. Illus. $4.50. A volume in the Science and Discovery Series, intended for high school students and general readers.

The Behavior of Plasticizers. Ibert Mellan. Pergamon, New York, 1961. 273 pp. Illus. $8.

Calculus and Analytic Geometry. Robert C. Fisher and Allen D. Ziebur. Prentice-Hall, Englewood Cliffs, N.J., 1961. 781 pp. Illus. Trade, $12.65; text, $9.50.

A Collection of Tables and Nomograms for the Processing of Observations Made on Artificial Earth Satellites. I. D. Zhongolovich and V. M. Amelin. Translated from the Russian by Prasenjit Basu. Pergamon, New York, 1961. 200 pp. $15.

College Chemistry. A systematic approach. Harry H. Sisler, Calvin A. Vander Werf, and Arthur W. Davidson. Macmillan, New York, ed. 2, 1961. 719 pp. Illus. $7.50.

Directory of Industrial Research Laboratories in New York State. New York State Department of Commerce, Albany, 1960. 302 pp. Lists 1008 laboratories, including 628 which accept work from outside organizations and 31 in educational institutions and four other agencies.

Discourses on Bodies in Water. Galileo Galilei. Translated by Thomas Salusbury. Introduction and notes by Stillman Drake. Univ. of Illinois Press, Urbana, 1960. 115 pp. Illus. $5. A facsimile, except for page numbering, of Salusbury's original translation, printed in London by William Leybourn (1663).

Elements of Nuclear Engineering. Glenn Murphy. Wiley, New York, 1961. 226 pp. Illus. $7.50.

The Fermi Surface. W. A. Harrison and M. B. Webb, Eds. Wiley, New York, 1960. 371 pp. Illus. $10. Proceedings of the international conference held at Cooperstown, N.Y., in August 1960, and attended by 90 scientists from seven countries.

Fracture Systems and Tectonic Elements of the Colorado Plateau. Publ. in Geology, No. 6. Vincent C. Kelley and N. James Clinton. Univ. of New Mexico Press, Albuquerque, 1960. 104 pp. + 3 maps. $2.75.

Gas Chromatography, 1960. R. P. W. Scott, Ed. Butterworths, Washington, D.C., 1960. 483 pp. Illus. $17.50. Proceedings of the third symposium organized by the Society of Analytical Chemistry and the Institute of Petroleum, Edinburgh, June 1960.

The International Dictionary of Physics and Electronics. Walter C. Michels, Editor-in-Chief. Van Nostrand, New York, ed. 2, 1961. 1355 pp. Illus. $27.85.

An Introduction to the Theory of Vibrating Systems. W. G. Bickley and A. Talbot. Oxford Univ. Press, New York, 1961. 252 pp. Illus. $4.80.

Magneto-Fluid Dynamics. Publ. 829. F. N. Frenkiel and W. R. Sears, Eds. Natl. Acad. of Sciences–Natl. Research Council, Washington, D.C., 1961 (reprinted from *Reviews of Modern Physics* **32**, No. 4, pp. 693–1032). $4.

Mineral Metabolism. An advanced treatise. vol. 1, pt. B, *Principles, Processes, and Systems.* C. L. Comar and Felix Bronner, Eds. Academic Press, New York, 1961. 552 pp. $14.50.

Modern Aspects of the Vitreous State. J. D. Mackenzie, Ed. Butterworths, Washington, D.C., 1960. 234 pp. Illus. $9.50.

Modern Factor Analysis. Harry H. Harman. Univ. of Chicago Press, Chicago, Ill., 1961. 485 pp. Illus. $10.

Name Index of Organic Reactions. J. E. Gowan and T. S. Wheeler. Interscience, New York, ed. 2, 1960. 301 pp. $8.50. A compilation of 739 reactions referred to by the name of chemists in the current literature and textbooks; original edition was published by the Society of Chemical Industry (1950).

Nuclear Propulsion. M. W. Thring, Ed. Butterworths, Washington, D.C., 1960. 300 pp. Illus. $9.50.

Organo-Metallic Compounds. G. E. Coates. Methuen, London; Wiley, New York, ed. 2, 1960. 379 pp. Illus. $7.50.

Planets, Stars, and Galaxies. An introduction to astronomy. Stuart J. Inglis. Wiley, New York, 1961. 484 pp. Illus. $6.75.

Power Reactor Technology. James K. Pickard *et al.*, Eds. Van Nostrand, Princeton, N.J., 1961. 426 pp. Illus. $11.25.

The Precambrian Geology and Geochronology of Minnesota. Bulletin 41. Samuel S. Goldich, Alfred O. Nier, Halfdan Baadsgaard, John H. Hoffman, and Harold W. Kruegar. Univ. of Minnesota Press, Minneapolis, 1961. 214 pp. + maps. Illus. $4.

Specifications and Criteria for Biochemical Compounds. Publ. 719. Division of Chemistry and Chemical Technology. Natl. Acad. of Sciences–Natl. Research Council, Washington, D.C., 1960. $1 (loose leaf). This publication, covering 113 biochemicals, resulted from a 5-year study of ways to improve the quality of chemicals available for biochemical research by establishing criteria, standards, or specifications which can be used for describing such chemicals, particularly with regard to purity. Supplements will be issued, probably annually.

Theories of Engineering Experimentation. Hilbert Schenck, Jr. McGraw-Hill, New York, 1961. 249 pp. Illus. $7.

Theory of Formal Systems. Raymond M. Smullyan. Princeton Univ. Press, Princeton, N.J., 1961. 154 pp. Paper, $3.

Unified Calculus and Analytic Geometry. Earl D. Rainville. Macmillan, New York, 1961. 742 pp. Illus. $8.50.

Reports

"Bioconvection Patterns" in Cultures of Free-Swimming Organisms

Abstract. The moving polygonal patterns in dense cultures of *Tetrahymena* and other ciliates and flagellates look like "Benard cells," but are not due to thermal convection. They seem to be due to a similar dynamic instability that occurs when the energy input is internal and mechanical. The high concentration in the patterns may be useful in fertilization.

The purpose of this report is to call renewed attention to the physics of the curious streaming patterns observed in dense cultures of free-swimming organisms. Such patterns are well known for several different kinds of ciliates and flagellates—bull sperm (*1*) *Euglena* (*2*), *Tetrahymena* (*3*), and *Arbacia* larvae (*4*)—but there seems to have been no theoretical analysis and little systematic experimental analysis, except in the work of Loefer and Mefferd (*3*), on *Tetrahymena pyriformis*.

In a *T. pyriformis* culture 1 or 2 cm deep and a few centimeters across, in an open or closed vessel, the organisms are concentrated into flowing patterns of polygonal shape, as seen from above. Individual organisms swim upward in the centers of the polygons and move outward a few millimeters to the edges of the polygons where they fall to the bottom in dense, almost vertical sheets or skeins. The size of the polygons and the sharpness of their boundaries depend on the density and age of the culture, but the density of organisms in the falling sheets may reach the order of 100 times the density in the centers of the polygons. Loefer and Mefferd showed that the liquid is in motion in these sheets, carrying the organisms (and inert particles as well) faster than the individuals can swim. They also showed that the patterns are formed only when the depth of the culture is several millimeters or more and when the average density of motile organisms is more than 150,000 per milliliter. Loefer and Mefferd further showed that the patterns are unaffected by *p*H, temperature, osmotic pressure, anaerobic conditions, ultraviolet, surface-active chemicals, viscosity, or age, except as these factors affect motility. The speeds of fluid motion are enough to carry an individual organism to the bottom and back to the top in a time of the order of 15 to 30 sec; the patterns change completely in this time, and after stirring they re-form in this time or less.

A number of additional observations and experiments have now been made on the patterns in *T. pyriformis*. They show that surface-tension explanations can be ruled out, because of (i) the random angles of intersection of the polygon edges with each other and with the walls, (ii) the fact that the pattern shapes are indifferent to underfilling or overfilling of an open glass container, and (iii) the fact that they are indifferent to glass cover slips covering or half-covering the solution. Magnetic fields of 9000 gauss had no effect on the shapes of the patterns or on their rate of formation or change either in an ordinary *T. pyriformis* culture or in a conducting 1-percent NaCl solution of an NaCl-adapted strain. Strong light, heat, or electrodes (a-c) push the patterns "away," but this can be explained as the effect of thermal convection on already formed patterns.

Possible explanations of the patterns might include (i) directed motion of individuals due to exhaustion of oxygen or nutrients in the centers of the polygons; (ii) thermal convection (suggested by N. Spratt); (iii) viscous attachment of individuals (suggested by M. Sussman) or reduction of swimming on collision (suggested by F. Child), with the consequent formation of dense aggregates which fall; (iv) an essential dynamic instability in a group of randomly free-swimming organisms heavier than water (like the instabilities in a group of hovering helicopters if some get in the downdraft of others); or (v) dynamic instability due to density inversion when heavy organisms tend to swim to the top of the liquid (like the instability and downstreaming patterns observed when heavy powder is sprinkled on a water surface) (suggested by R. Donnelly).

The first explanation seems unlikely because of the speed of self-stirring of the solutions and the indifference of the patterns to anaerobic conditions. The second explanation is supported by the close resemblance of the polygonal patterns to the "Benard cells" of classical thermal convection experiments; and in fact the patterns might well be called "bioconvection patterns." But this explanation is ruled out by a crucial experiment of R. Donnelly's, in which he placed a culture dish of *T. pyriformis* on ice and found that the patterns re-formed as rapidly as before, in spite of the negative (stabilizing) thermal gradient (*5*). The third explanation seems unlikely because there is no evidence for it under the microscope (*6*), and because washed cultures in pure water (with any high-viscosity filaments presumably removed) still show the same patterns.

The fourth or fifth explanations seem the most probable. They are supported by the resemblance to "Benard cells" (thermal instability), especially in the requirement of a minimum critical depth and a minimum critical density for formation of the patterns, the density of motile organisms being presumably the biological analogue of the energy input in the thermal case. The patterns can also be stabilized, like Benard cells, by mechanical obstacles in the solution, such as glass rods and plates and bubbles, or strings hanging from the top surface of the culture. Studies of *T. pyriformis* in a sucrose solution as dense as the organisms, or denser, might permit a decision between the last two alternatives.

Dynamic instabilities leading to channeled streaming patterns are well known in the thunderstorm instabilities of meteorology and in the "rip tide" streams where ocean breakers push onto a straight shoreline (*7*). It is interesting to see that they may be of major importance in determining the aggregate and concentration behavior of living organisms where the energy input is from an internal metabolic source in each individual rather than from an external source. Possibly the Chandrasekhar theory of thermal instabilities in hydrodynamic systems can be modified to explain these bioconvection patterns and their sizes, veloc-

---

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to contributors" [*Science* **125**, 16 (1957)].

ities, and critical parameters. The increased concentrations in bioconvective streams might be important in fertilization and in initial streaming and schooling behavior in many small marine organisms (*8*).

JOHN R. PLATT*
Marine Biological Laboratories, Woods Hole, Massachusetts

References and Notes

1. L. Rothschild, *Nature* **163**, 358 (1949).
2. W. J. Robbins, *Bull. Torrey Botan. Club* **79**, 107 (1952).
3. J. B. Loefer and R. B. Mefferd, Jr., *Am. Naturalist* **86**, 325 (1952).
4. L. Rebhun, unpublished data.
5. R. J. Donnelly, unpublished data.
6. P. Dunham, unpublished data.
7. W. Bascom, *Sci. American* **203**, 81 (1960).
8. This problem was called to my attention by Burr Steinbach and Nelson Spratt. I am indebted to the colleagues mentioned, and to a number of others, for helpful discussions; I wish to thank Philip Dunham for the preparation of several *T. pyriformis* cultures, Leonard Rebhun for cultures of *Arbacia* larvae, and Irvin Isenberg for assistance with the magnetic field experiments. The work was assisted by a grant from the U.S. Public Health Service.
* Present address: Physics Department, University of Chicago, Chicago, Ill.

12 January 1961

Recording of Single Unit Activity in Isolated Central Nervous Tissue

Abstract. The retina and attached segment of optic nerve isolated from the rabbit were maintained in a functioning state in vitro. Microelectrodes, introduced into the nerve, recorded unit discharges in response to light stimuli. The characteristics of these evoked discharges are described.

Nervous tissue that has been isolated from the host and is being maintained in a suitable incubation medium offers three advantages for experimentation not shared by the same tissue studied in the intact animal: (i) Its chemical and physical milieu can be precisely defined and easily altered. (ii) Certain metabolic processes can be monitored continuously during an experiment. (iii) The tissue can be removed without trauma at any instant for anatomical or chemical analysis. To be most useful, such an in vitro preparation must have been isolated without irreversible damage, must be maintained in a nearly physiological state, and must be amenable to measurement of function.

Rabbit retina has been used as an example of central nervous gray matter that is suited to in vitro study. It can be isolated and maintained in an incubating fluid without significant shifts in intracellular electrolytes (*1*) and with maintenance of function as recorded by gross electrodes (*2*). The present report describes measurement of single unit activity in this isolated preparation.

Details of the methods used in isolating and incubating the tissue have been presented (*2*). In brief, an eyeball with 1 cm of optic nerve is removed from an anesthetized, dark-adapted rabbit; and, as rapidly as possible, the retina and the attached segment of nerve are separated, under cooled medium, from the other tissues of the eye. The nerve is mounted on two 24-gauge platinum wires, one tied to the cut end of the nerve and the other encircling it near the disk. Besides their use as gross electrodes, these wires serve to suspend the preparation in the incubation medium and to fix the nerve for the introduction of the microelectrode. The medium resembles cerebrospinal fluid in electrolyte composition, is equilibrated with 5 percent CO_2 and 95 percent O_2, and is maintained at 30°C.

In the experiments reported here, the microelectrode was of tungsten, sharpened electrolytically to a tip diameter of less than ½ μ and insulated with vinyl lacquer according to the method of Hubel (*3*). It was advanced by means of a micrometer drive into the nerve about 4 mm from the disk at an angle of 45° from normal. One of the gross electrodes served as electrical reference. The signal was led through a high-input-impedance cathode follower to a preamplifier, having a band

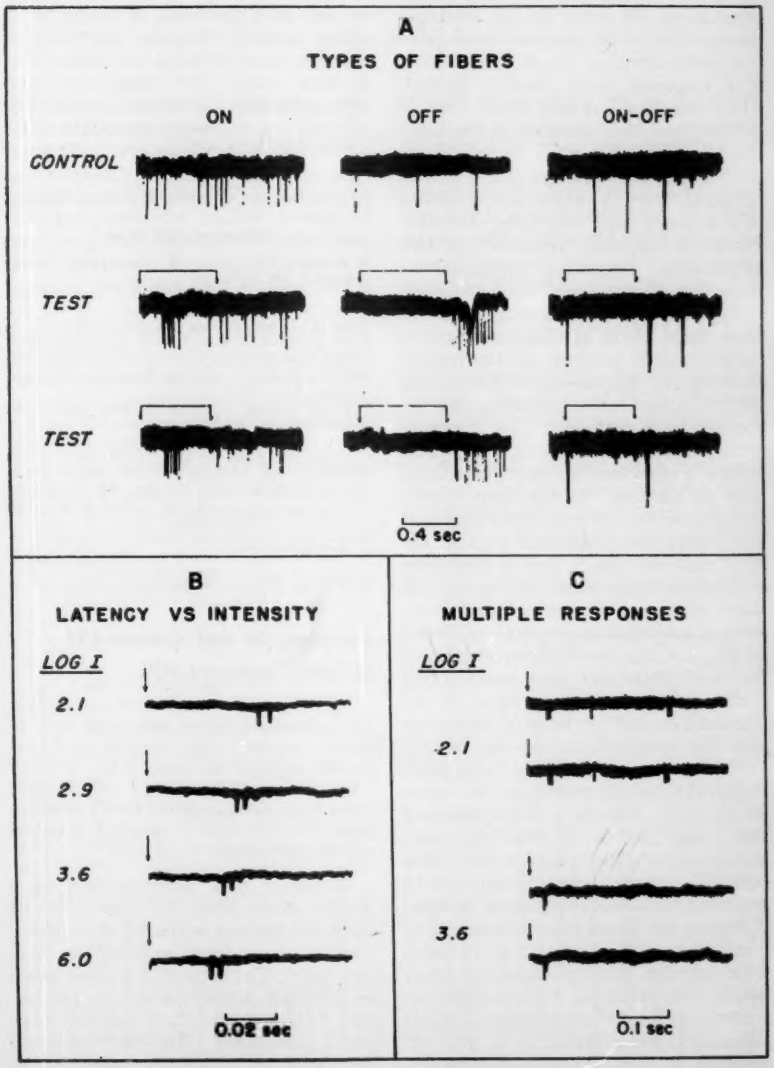


Fig. 1. (*A*) Spontaneous and evoked activity recorded from three fibers of different response types. (*B*) Relation of response to stimulus intensity in an "on" fiber. (*C*) Multiple responses following stimuli of low but not of high intensity. Durations of the longer light stimuli are indicated by horizontal lines above traces in (*A*). The times of presentation of the short (about 10 μsec) light stimuli are indicated by arrows in (*B*) and (*C*).

pass of from 1 to 30,000 cy/sec, on to a dual-beam oscilloscope. Short light stimuli, with a duration of the order of 10 μsec, were provided by a Grass photostimulator. Longer stimuli were provided by a 6-volt tungsten filament lamp. The entire retina was illuminated.

With the advance of the microelectrode, the sudden appearance of deflections of brief duration and uniform amplitude that were modifiable by light was taken as evidence that an active unit was being sampled. By this criterion, from two to six fibers were sampled in a single penetration of the nerve. An individual fiber could be observed for periods lasting from a few seconds to 90 min. In all instances the polarity of the responses was positive with respect to the gross electrode. The responses were sharply peaked. Their amplitude ranged from 0.05 to 0.3 mv, and their duration at the baseline was about 0.6 msec. In most cases the uniform amplitude of the responses recorded from a given site indicated that a single unit was being sampled, though occasionally responses of two amplitudes, suggesting simultaneous recording of two units, were observed.

Figure 1*A* shows records obtained from three fibers of different response types. In each instance the top record, showing the spontaneous activity, and the two lower records, showing the responses to a prolonged light stimulus, were taken in close temporal sequence. Fibers were observed that responded only to the "on" of the light, others that responded only to the "off," and still others that responded both to the "on" and the "off." This is consistent with observations made in vivo (*4*). Almost all fibers showed a rather high level of spontaneous activity. As shown in Fig. 1*A*, the spontaneous activity of the "on" fibers was diminished during the latent period between onset of the illumination and the burst of responses, and the spontaneous activity of the "off" fibers was diminished throughout the period of illumination. At occasional sites, deflections were recorded that could not be modified by light, though in all other respects they were identical to the spontaneous activity recorded from fibers responsive to light.

Figure 1*B* shows the response of an "on" fiber to a short (about 10 μsec) light stimulus, varying in intensity from about 130 to about 10^6 ft-ca. As intensity increased over this range, latency diminished by a factor of 2, but the number of evoked discharges did not change.

Figure 1*C* shows the multiple responses sometimes observed after short stimuli of low intensity. Though the successive intervals between discharges, or pairs of discharges, were not equal, they were reproducible from stimulus to stimulus. The number of response groups and the lengths of the intervals between them changed with the intensity of the stimulus. At higher intensities only the first group of discharges remained. It is possible that these multiple responses are related to the rhythmic activity observed in the cortex of man after photic stimulation (*5*).

Since several important features of electrical activity—the level of spontaneous discharge, the response of different types of fibers, the occurrence of multiple discharges—are revealed only by the microelectrode, it should be a useful addition to gross electrodes in experiments correlating the function of nervous tissue with metabolism and with changes in the chemical milieu (*6*).

ADELBERT AMES III
BENNETT S. GURIAN
Neurosurgical Service,
Massachusetts General Hospital, Boston

References and Notes

1. A. Ames III and A. B. Hastings, *J. Neurophysiol.* **19**, 201 (1956).
2. A. Ames III and B. S. Gurian, *ibid.* **23**, 676 (1960).
3. D. H. Hubel, *Science* **125**, 549 (1957).
4. W. K. Noel, *Studies on the Electrophysiology and the Metabolism of the Retina* (U.S. Air Force School of Aviation Medicine, Randolph Field, Tex., 1953), p. 6.
5. J. S. Barlow, *Electroencephalog. and Clin. Neurophysiol.* **12**, 317 (1960).
6. This investigation was supported in part by a research grant (M-1230) from the National Institute of Mental Health, U.S. Public Health Service, and in part by a contract from the U.S. Air Force (Office of Scientific Research, AF-49-638-98).

27 December 1960

Strontium-90 and Cesium-137 in North American Milk

Abstract. The strontium-90 and cesium-137 concentrations in powdered milk in North America vary roughly with the specific activity of rain. The Sr^{90}/Cs^{137} ratios in over 800 powdered milk samples taken from 60 stations in North America from 1957–60 have a standard deviation of only 44 percent.

Powdered milk samples taken on a weekly basis from 1957 to 1960 at some 60 stations scattered over North America have been analyzed for Sr^{90} and Cs^{137}. The network was maintained by the Los Alamos Scientific Laboratory (*1*), and the Cs^{137} analyses were performed there. The Sr^{90} analyses were done under the supervision of the geochemistry laboratory, Columbia University (*2*). The raw data have been given in various reports by the Health and Safety Laboratory of the Atomic Energy Commission (*3*), and the Cs^{137} data from 1957–1958 have been discussed by Langham and Anderson (*4*) and by Anderson (*5*).

This program was designed to give information on the following subjects: (i) the average Sr^{90} and Cs^{137} levels in the North American diet, (ii) the mechanism by which these isotopes enter plant tissue and milk, and (iii) the relation of Cs^{137} and Sr^{90} concentrations.

It has been shown in a variety of studies (*6*) that the Sr^{90} concentration in Western diet is about 1.2 times the concentration in milk in micromicrocuries of Sr^{90} per gram of calcium. Since milk is the easiest food to sample in a comprehensive manner, it is the best food to monitor. The average values provided by the U.S. Public Health Service's networks for testing powdered milk and liquid milk are given in Table 1. There is no systematic difference between the Sr^{90} concentration in powdered and liquid milk from the same general area. The data are grouped by half years, rainfall, and geography. From these data the Sr^{90} concentration in the average North American diet is calculated for each year. The concentration of Sr^{90} in the diet increased each year from 1957 through 1959, but it appears that it will drop to nearly half the 1959 value in 1960. Similar results for Cs^{137} are shown in the lower part of Table 1.

The relative contribution to the concentration of Cs^{137} and Sr^{90} in plants by direct absorption from rain and by absorption through the soil is of great importance since it determines the concentration of these fission products in the diet in the long-term situation. R. S. Russell and his co-workers (*7*) have conducted experiments which suggest that for the typical milk-producing pasture in Britain, only 20 percent of the Sr^{90} in the plants under the fallout conditions up to 1958 was introduced through the soil. They assumed that absorption from the soil is the same for the vertical profile produced by fallout as if the Sr^{90} is homogenized in the upper 4 in. of soil.

The maintenance of the milk networks of the Los Alamos Scientific Laboratory and the Public Health Service through 1961 should answer this question empirically for the North American continent as a whole. The specific activity of Sr^{90} in rain in the spring of 1960 was down from that in 1959 by a factor of about 5, whereas the total cumulative deposit had only increased by 5 to 10 percent. Thus the milk levels in the summer of 1960 should give for the continent the first estimate of the relative contribution from these sources. Although the data

Table 1. Summary of Sr^{90} and Cs^{137} in North American milk. The numbers in parentheses indicate the number of stations.

Sector	Annual rainfall (in.)	1957 First half	1957 Year	1958 First half	1958 Year	1959 First half	1959 Year	1960 First half	1960 Year	Percent of population
Sr^{90} in micromicrocuries per gram of Ca										
Eastern U.S.	40–60	6.0 (12)	6.5 (32)	7.5 (27)	8.7 (78)	15.8 (27)	11.2 (47)	11.0 (54)		0.46
Northwest coast	40–60	5.2 (8)	4.6 (16)	7.5 (8)	6.8 (19)	13.0 (7)	11.7 (11)	10.8 (9)		0.06
Midwest	20–40	6.5 (16)	6.4 (35)	6.4 (32)	7.5 (87)	10.4 (26)	9.8 (47)	10.5 (67)		0.38
Plains states	10–20	4.6 (10)	6.1 (28)	8.8 (21)	8.7 (63)	11.6 (28)	11.4 (48)	9.1 (50)		0.09
West and Southwest	irrigation	2.2 (13)	2.5 (25)	2.8 (14)	3.4 (28)	9.1 (5)	6.0 (10)	3.5 (19)		0.01
North American av. weighted for population			6.2		8.1		10.7		~7	
North American total diet (est.)			7.4		9.7		12.7		~8	
Cs^{137} in micromicrocuries per gram of K										
Eastern U.S.	40–60		51 (54)		61 (84)		86 (56)		76 (1)	0.46
Northwest coast	40–60		41 (38)		53 (45)		100 (16)		—	0.06
Midwest	20–40		46 (57)		53 (137)		61 (61)		38 (1)	0.38
Plains states	10–20		47 (45)		51 (89)		60 (45)		55 (4)	0.09
West and Southwest	irrigation		29 (59)		29 (69)		34 (11)		—	0.01
North American av. weighted for population			49.1		56.7		74.3			

are as yet quite limited, the results for the second quarter of 1960 (8.8 $\mu\mu c$ of Sr^{90} per gram of Ca) show milk values down by a factor of 2 since 1959 (17.6 $\mu\mu c$ of Sr^{90} per gram of Ca). This would suggest that at least half of the Sr^{90} in milk has been a result of direct absorption.

There are some other effects which show that direct absorption was quite important even prior to 1960. The first of these is that the Sr^{89}/Sr^{90} ratio in the milk was about half of that in the rain and much higher than that in the soil. The Sr^{89}/Sr^{90} ratios suggested a mean delay time of 2 mo from the time the Sr^{90} fell in the rain and its entry into the milk. This could result from an equal contribution of very recent (1 mo) Sr^{90} directly from rain mixed with old Sr^{90} from the soil which carried virtually no Sr^{89}. A second point is that the Cs^{137} and Sr^{90} concentrations in milk vary closely with the specific activity of the rain. Figure 1 gives these measurements for the Burlington, Wash., station as well as the average quarterly specific activity of the rain. The concentration of these fission products in the milk is essentially independent of the total rainfall. This same relation holds for the average continental values. Third, Langham and Anderson (*4*) showed that the Cs^{137} values in milk of the plains states are very sensitive to deposition of fresh fission products from Nevada tests. This, coupled with the strong bonding of cesium to the soil and its difficulty of passing to the plant through the roots, suggests that the Cs^{137} absorption occurs largely in the upper parts of the plants, directly from rain. The uniform Sr^{90}/Cs^{137} ratios over a wide variety of conditions indicate that the same mechanism holds for Sr^{90} as well.

When all of the milk data are available for the second and third quarters of 1960, it should be possible to make a fairly reliable prediction of the relative importance of the rate and cumulative factors for the North American continent as a whole.

In the event of a nuclear disaster of local or global dimensions it is desirable to be able to monitor large quantities of food for the long-lived isotopes, Cs^{137} and Sr^{90} in particular. Since the Cs^{137} assay may be done in a matter of minutes with a Los Alamos Scientific Laboratory type of counter, and since the Sr^{90} determination requires many days, it is of interest to determine the accuracy with which the Sr^{90} concentration may be estimated from a Cs^{137} measurement. Powdered milk is ideal in this regard, for it is relatively simple to handle and it may be representative of a large area.

In order to determine the accuracy of such a procedure, the ratios of Sr^{90} per gram of calcium to Cs^{137} per gram of potassium were calculated for all samples of the Los Alamos Scientific Laboratory network for which these data were currently available. The total number of samples was about 800. The North American average over 50 stations and 4 yr was

$$\frac{\mu\mu c\ Sr^{90}/g\ Ca}{\mu\mu c\ Cs^{137}/g\ K} = 0.17$$

with a standard error on this mean of ± 0.02. The *standard deviation* based on the entire array was 44 percent of the mean. Thus a single determination of the Cs^{137} content of a randomly selected powdered milk sample taken anywhere in the United States will give the Sr^{90} concentration well within a factor of 2 in accuracy at the 95-percent confidence level. Such accuracy is

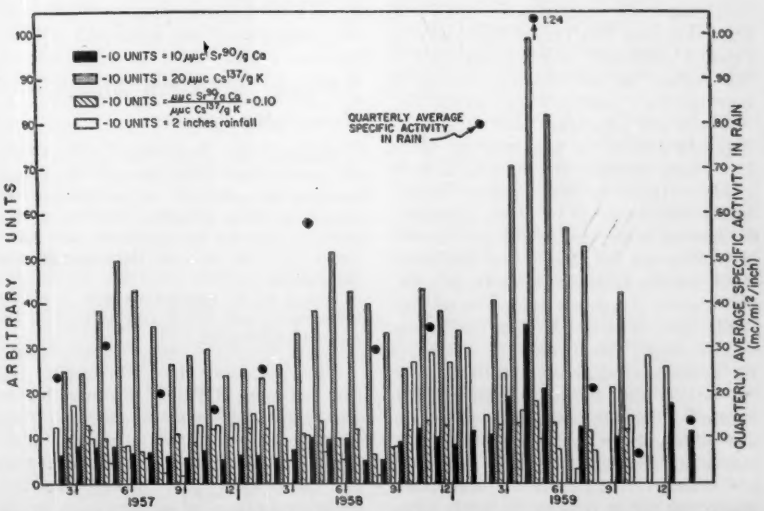


Fig. 1. Comparison of concentrations of cesium-137 and strontium-90 in milk with total rainfall and specific activity of rain at Burlington, Washington, 1957–60.

Table 2. Standard deviations of the average ratios of Sr^{90} to Cs^{137} for five representative stations in North America.

Station	Annual rainfall (in.)	Av. ratio, Sr^{90}/Cs^{137}	Standard deviation (%)
Burlington, Wash.	40–60	0.11	23
Tipton, Calif.	irrigation	0.115	42
St. Albans, Vt.	40–60	0.13	30
Aberdeen, Miss.	40–60	0.27	18
Springfield, Mo.	20–40	0.22	30
			Av. 29

entirely adequate for large-scale monitoring purposes. Presumably the same value would hold for the rest of the Western world and might hold for the whole world. Limited data from a world-wide network of about 15 stations are concordant with this assumption.

A further question, however, is whether the accuracy of the estimate can be improved if the sampling is restricted in some way. First, the standard deviation was calculated for five representative stations for the entire 4-yr period. The results are shown in Table 2.

The combination of the analytical errors probably yields a standard deviation of the ratio of about 15 percent. The average deviation of 29 percent for these five representative stations therefore seems to show a real variation in this ratio in the samples, but it is clear that the estimate of the Sr^{90} concentration from a Cs^{137} assay can be improved if some history is available on the particular station. It can also be observed from these data that the average Sr^{90}/Cs^{137} ratio for a given station remained within the standard deviation from year to year. This suggests that over this period there was no marked difference in the character of the fallout or the relative routes of entry of Cs^{137} and Sr^{90} into grass.

There are significant and reproducible differences in the average Sr^{90}/Cs^{137} ratio between the stations in each group. Thus in the eastern sector, where rainfall is 40 to 60 in. annually, Aberdeen, Miss., has an average ratio of 0.27, whereas St. Albans, Vt., has about 0.15. In the Midwest 20 to 40 in. area, the highest consistent station is Springfield, Mo., with 0.22, and the lowest is LaGrange, Tex., with 0.13. There is no systematic difference with latitude or, within the station variation, with rainfall. Thus the average values for the different groups, each with their standard error of the mean, are: East (40–60 in.), 0.19 ± 0.02; northwest coast (40–60 in.), 0.14 ± 0.02; Midwest (20–40 in.), 0.19 ± 0.02; High Plains states (10–20 in.), 0.19 ± 0.03; West and Southwest (irrigation), 0.14 ± 0.03.

The differences in the average ratio of Sr^{90} to Cs^{137} between individual stations (as much as a factor of 2) appear to be real, but the reason for these differences is as yet obscure.

J. L. KULP
A. R. SCHULERT
E. J. HODGES

Geochemistry Laboratory,
Lamont Geological Observatory,
Palisades, New York

E. C. ANDERSON
W. H. LANGHAM

Los Alamos Scientific Laboratory,
Los Alamos, New Mexico

References and Notes

1. This work was performed under the auspices of the U.S. Atomic Energy Commission.
2. This article is Lamont Geological Observatory Contribution No. 487. The phase of the investigation carried out at the Lamont Geological Observatory was supported by the U.S. Atomic Energy Commission under contract AT(30-1)-1656. Rieta Slakter Hirshman was in charge of the Lamont analytical program, and Homer McFadden assisted in the laboratory. Various commercial laboratories analyzed most of the samples under contract with the Health and Safety Laboratory of the U.S. Atomic Energy Commission. These included Controls for Radiation, Inc., Isotopes, Inc., Nuclear Science and Engineering Corp., and Tracerlab.
3. Health and Safety Laboratory, U.S. Atomic Energy Commission Fallout Program Report Nos. HASL-42, 51, 65, 69, 77, 84, 88, 95, New York Operations Office, U.S. Atomic Energy Commission.
4. W. H. Langham and E. C. Anderson, *Health Physics* **2**, 30 (1958).
5. E. C. Anderson, *Science* **128**, 882 (1958).
6. J. L. Kulp and R. Slakter, *ibid.* **128**, 85 (1958); F. J. Bryant, A. C. Chamberlain, G. S. Spicer, M. S. W. Webb, *Brit. Med. J.* **1958**, 1371 (1958); P. M. Bird and P. G. Mar, *Dept. Natl. Health and Welfare Can. Publ. No. CNHW (RP-2)* (Apr. 1959); HASL-90, Health and Safety Laboratory, U.S. Atomic Energy Commission.
7. J. D. Burton, G. M. Milbourn, R. S. Russell, *Nature* **185**, 498 (1960).

14 November 1960

Transport of Oxygen through Hemoglobin Solutions

Abstract. An expression is derived for the steady-state diffusion rate of oxygen through a solution or suspension of oxygen-carrying particles. Several special cases of interest are discussed and compared with the data of Hemmingsen and Scholander. Their observed dependence of the rate of specific oxygen transport on pressure and *p*H is consistent with the present expression.

The discovery by Scholander (*1*) that oxygen diffuses through hemoglobin solution many times faster than nitrogen has stimulated considerable interest (*2*). More recently, Hemmingsen and Scholander (*3*) showed that this specific transport of oxygen is abolished when the liquid film is opposed by a slight back pressure of oxygen. These investigators also pointed out the need for a unified theory to explain all of their data. In the present report, a simple general expression is derived which not only accounts for their results but which may also be useful as a quantitative guide for further experimental work in this direction.

Consider the portion of liquid enclosed in an imaginary cylinder in the diffusion layer as depicted by the broken line in Fig. 1. Let the axis of the cylinder be parallel to the x-axis, which represents the direction of diffusion, and let A and $x_1 - x_2$ represent, respectively, the cross-sectional area and length of this imaginary cylinder. We have, for the concentration C_i of bound O_2 inside the oxygen-carrying particles:

$$C_i \equiv f(p) = cpL'/L \qquad (1)$$

where c is the concentration of total hemoglobin or myoglobin inside the oxygen-carrying particles; p is the partial pressure of O_2; $L' = dL/dp$; and for myoglobin, $L = 1 + Kp$, and for hemoglobin, $L = 1 + K_1p + K_1K_2p^2 + K_1K_2K_3p^3 + K_1K_2K_3K_4p^4$; and K, K_1, K_2, K_3, and K_4 are equilibrium constants for oxygenation reactions (*4*).

Also, for the concentration C_o of dissolved O_2 in water outside the particles, we have

$$C_o = kp \qquad (2)$$

and for the concentration C_p of dissolved O_2 in the particles, we have

$$C_p = k'p \qquad (3)$$

where k and k' are the Henry's law constants.

Differentiating Eq. 1 with respect to p gives

$$f'(p) \equiv df(p)/dp = c(pLL'' + LL' - pL'^2)/L^2 \qquad (4)$$

where $L'' \equiv dL'/dp$.

The steady-state diffusion rate of oxygen molecules in the x-direction, averaged over the entire volume of the imaginary cylinder, is

$$q = \frac{-1}{A(x_2 - x_1)}\left[\int_{v_o} D_o k \frac{\partial p}{\partial x}\, dv + \int_{v_i} (D_i + D_p)\left\{f'(p) + k'\right\}\frac{\partial p}{\partial x}\, dv\right] \qquad (5)$$

where D_o, D_i, and D_p represent, respectively, the diffusion coefficient of dissolved O_2 outside the oxygen-carrying particles, that inside the particles, and the diffusion coefficient of the particles themselves. The integration of the first term in Eq. 5 is to be carried out over the total volume, v_o, of the imaginary cylinder outside the particles, and the integration of the second term is over the total volume, v_i, inside the particles.

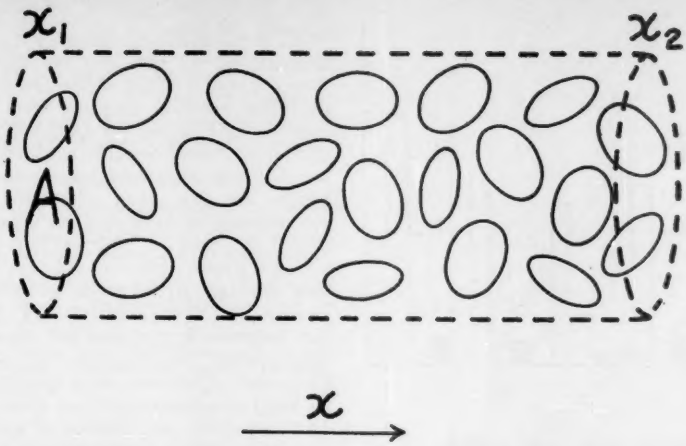


Fig. 1. Diagrammatical representation of a volume element in the diffusion layer containing oxygen-carrying particles represented by the ellipsoids.

The following three particular cases are of special interest:

1) For the diffusion of nitrogen or any other nonreacting gas, $f'(p) = 0$. Consequently, we can make the approximation that $D_0 k \simeq D_1 k'$ and that

$$\partial p/\partial x = (p_2 - p_1)/(x_2 - x_1) \equiv \Delta p/\Delta x = dp/dx$$

where p_1 and p_2 are the partial pressures of the diffusing gas at x_1 and x_2 respectively. Equation 5 then simplifies to the familiar form

$$q = - D_0 \, (\Delta p/\Delta x) k \qquad (6)$$

2) For the diffusion of oxygen at low partial pressures, $f'(p) > k'$ or k. Hence the second integral in Eq. 5 gives rise to an increased rate of diffusion as observed by Scholander (*1*).

3) For the diffusion of oxygen under high partial pressure, $f'(p) \to 0$. Hence the diffusion rate drops back to normal, as was found experimentally.

The dependence of steady-state diffusion rate on the partial pressure of oxygen can be conveniently illustrated by considering the special case of a very concentrated layer of immobilized myoglobin or hemoglobin solution or gel or a layer of packed erythrocytes. For such a special case we have

$$v_0 << v_1 \qquad (7)$$

$$Dp \to 0 \qquad (8)$$

$$\partial p/\partial x = \Delta p/\Delta x = dp/dx \qquad (9)$$

Substituting Eqs. 7, 8, and 9 in Eq. 5 gives

$$q = \frac{- D_1}{x_2 - x_1} \int_{p_1}^{p_2} [f'(p) + k'] dp \qquad (10)$$

For simplicity let us consider the case of myoglobin, for which $L = 1 + Kp$, $L' = K$, and $L'' = 0$; hence we have the equation

$$f(p) = cKp/(1 + Kp),$$
$$f'(p) = cK/(1 + Kp)^2 \qquad (11)$$

Substituting Eq. 11 in Eq. 10 and integrating gives

$$q = - D_1 \left(\frac{\Delta p}{\Delta x}\right) \left[k' + \frac{ck}{(1 + Kp_1)\,(1 + Kp_2)}\right] \qquad (12)$$

Therefore, at constant pressure gradient, $\Delta p/\Delta x$, the diffusion rate at low partial pressures decreases as p_1 and p_2 are raised. At sufficiently high partial pressures, the second term in Eq. 12 becomes negligible; consequently, the oxygen molecules diffuse as a nonreacting gas. Similarly, the integral in Eq. 10 can be evaluated for hemoglobin, but in this case graphical and numerical methods are probably more expedient. It may also be noted that, although $f(p)$ and $f'(p)$ for hemoglobin are *p*H-dependent, the effect of *p*H on diffusion is noticeable only at low oxygen pressure when $f'(p)$ is not negligible as compared to k', which is in agreement with the observations of Hemmingsen and Scholander (*3*).

JUI H. WANG*

Department of Theoretical Chemistry, University Chemical Laboratory, Cambridge, England

References

1. P. F. Scholander, *Science* **131**, 585 (1960).
2. G. Markus, *ibid.* **132**, 95 (1960); I. Fatt, *ibid.* **132**, 368 (1960).
3. E. Hemmingsen and P. F. Scholander, *ibid.* **132**, 1379 (1960).
4. G. S. Adair, *J. Biol. Chem.* **63**, 517 (1925).

* On leave of absence from the Department of Chemistry, Yale University, New Haven, Conn.

2 December 1960

Response Latencies of Female Rats during Sexual Intercourse

Abstract. A female rat, by operating a lever, causes the presentation of a potent male rat and subsequent sexual contact. The female shows contact-response latencies that vary according to the nature of the contact. Latencies after ejaculations are longer than those after intromissions, which in turn exceed those after mounts.

In recent years our knowledge of the sexual behavior of the rat has increased considerably, largely because of the work of Beach and of Larsson (*1*, *2*). The great majority of the studies that these and other workers have carried out focuses primary importance on the male's behavior; the female has come in for scant attention. The experiment reported here measures the effects of single copulations on the behavior of estrus female rats, in the context of an ongoing series of copulations.

The major difficulty encountered in a detailed study of the female's behavior stems from the male's apparent dominance in the control of the intercopulatory intervals during ad libitum intercourse. In order to investigate in detail the behavioral effects of single copulations on the female, therefore, it is necessary to provide a method by which she can control the timing of the copulations. One such method is to make each copulation contingent upon some measurable *arbitrary response* by the female.

Eight albino and seven hooded female rats, ranging in age from 6 to 20 mo, were used as subjects. None of the females had been spayed; four were sexually experienced. Sexually vigorous hooded males between 3 and 6 mo old serviced the females during experimental sessions. Between sessions the animals were segregated, kept in a constant 12-hour light cycle, and fed freely.

A wooden box, 1 ft square and 15 in. high, served as the experimental space. A lever of the sort commonly used in operant conditioning studies protruded from one wall of the box. Operation of the lever activated timing and counting equipment. A buzzer on the outside of the box sounded for 1 sec after a lever-press.

The females were trained to press the lever by making presentation of the male contingent upon successively closer approximations to the desired response. The time required to train each female ranged from 15 to 90 min. At least 2 wk separated final training and the first testing session. Behavioral heat was induced by subcutaneous injections of 0.1 mg of estradiol benzoate (Progynon, Schering) 72 hr before

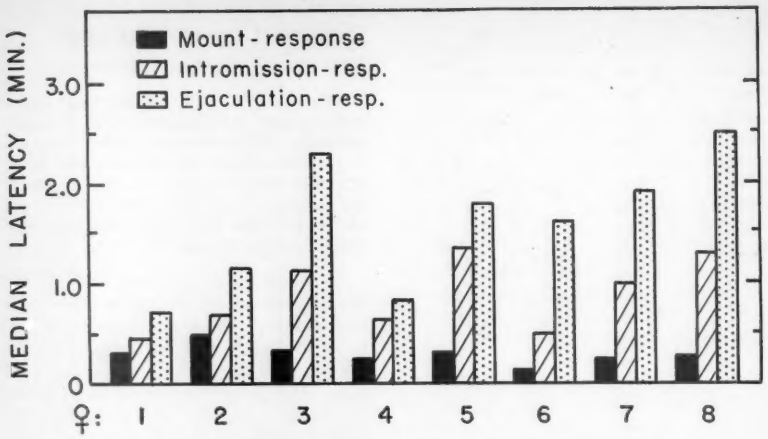


Fig. 1. Contact-response for individual animals during single sessions.

use and 1.0 mg of progesterone (Progestin, Organon, or Proluton, Schering) 6 hr before use.

During the test sessions, whenever the female pressed the lever the experimenter placed a male in the box. The male remained until copulation occurred. He was then removed and the copulation was recorded either as a mount, an intromission, or an ejaculation. The session continued for 1 hr or until the female had received five ejaculations. Tests on each female were usually spaced 21 days apart, although some sessions were run 14 days after the previous test.

Figure 1 displays the contact-response latencies of the eight females who completed at least four ejaculatory series during the experimental hour (the same eight animals are represented in Figs. 1 and 2). The data for each animal are considered individually, each bar representing the median latency after one kind of sexual event for a single session. Altogether the test was performed four times with one female, three times with another female, twice with five females, and once with four females. In each of these 21 cases the differences between medians were in the direction shown in the figure.

The bottom section of Fig. 2 displays contact-response latencies broken down with respect to performance in each of the ejaculatory series, so that each point is the average (median) for eight animals. Notice first that the latency values within a single series appear in the same order as they do when the data for each animal are considered individually: mount-response latencies are less than intromission-response latencies, which are less than ejaculation-response latencies. Now consider the time course of each of the curves. The mount-response latencies show very little change from series to series, varying but slightly around 0.3 min. The intromission-response and ejaculation-response latencies, on the other hand, show a decrease from the first to the third ejaculation, and then increase. There was only one instance of a fifth ejaculation-response latency, which is not included in the figure. Seven of the eight females represented in Fig. 2 showed minimal ejaculation-response latencies after the third or fourth ejaculation.

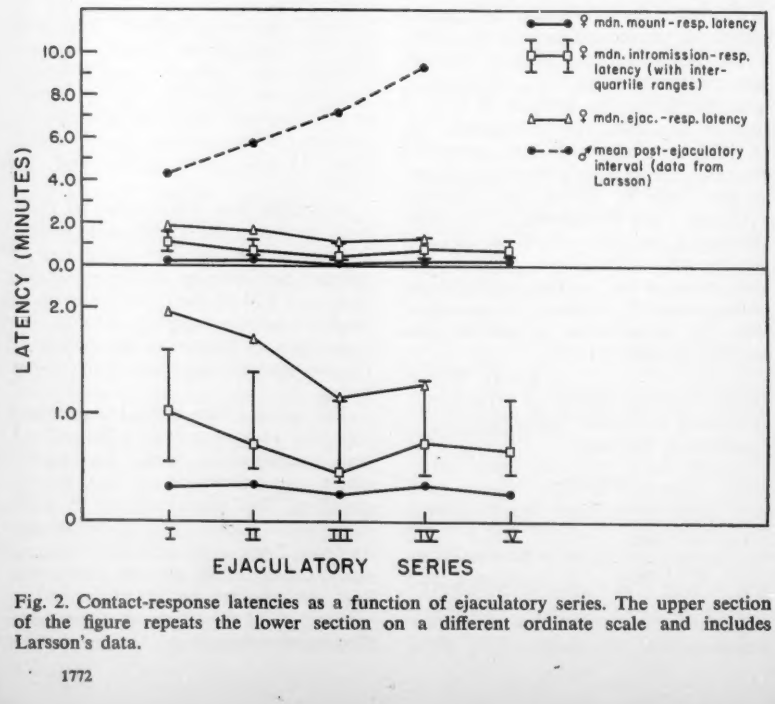


Fig. 2. Contact-response latencies as a function of ejaculatory series. The upper section of the figure repeats the lower section on a different ordinate scale and includes Larsson's data.

Figures 1 and 2 reveal the order in which female rats return to copulation-producing behavior after different sexual events. Male rats, copulating ad libitum, return to copulation in the same order. Secondly, there is some indication that female intromission-response latencies decrease in the middle of an experimental session. Males show decreased intercopulatory intervals after the first ejaculation. It is clear that the females' increased activity is not simply a reflection of a change in the male's condition, because fresh males were used for each ejaculatory series.

The broken line in the top part of Fig. 2 represents Larsson's data on the postejaculatory intervals for males who achieved four ejaculations during an hour test (*2*). For comparison, the female data are repeated in this part of the figure. Successive ejaculations cause progressively greater postejaculatory intervals in the male, while the female shows a decrease in ejaculation-response latencies toward the middle of the session. There is also a considerable difference in the absolute magnitudes of the two measures. Possible strain differences preclude a detailed comparison of this aspect of these data to those of Larsson. In observations of his own colony, however, Larsson has noted that the female's postejaculatory refractory period is "almost negligible" when compared to that of the male (*2*, p. 36). This observation is in agreement with the comparison shown in the figure.

In summary, it has been found that there are well-defined similarities and differences between the behavior of the male rat as observed during ad libitum intercourse and the behavior of the female as measured by the arbitrary

response technique. These relations exist within a single ejaculatory series and also in the dynamics of response associated with the progression from ejaculation to ejaculation (*3*).

GORDON BERMANT
Psychological Laboratories, Harvard University, Cambridge, Massachusetts

References and Notes

1. For a complete bibliography, see F. A. Beach, *Am. Psychologist* **18**, 730 (1958).
2. K. Larsson, *Conditioning and Sexual Behavior in the Male Albino Rat* (Almqvist, Stockholm, 1956).
3. This investigation was carried out under the tenure of a predoctoral fellowship from the National Institute of Mental Health, U.S. Public Health Service, and was supported in part by a grant (G-6435) from the National Science Foundation to Harvard University.

1 December 1960

Sparing of Folinic Acid by Thymidine

Abstract. Thymidine, which is inactive when added alone to *Pediococcus cerevisiae* (*Leuconostoc citrovorum*) 8081, was found to increase its growth in the presence of folinic acid. The addition of thymidine increased both the sensitivity of the folinic acid assay and the total growth yield. The mechanism of the synergistic effect of thymidine is briefly discussed.

Folinic acid (leucovorin) is known to meet the requirement of *Pediococcus cerevisiae* (*Leuconostoc citrovorum*) 8081 for the citrovorum factor, whereas the related pteroylglutamic acid is very inefficient (*1*). Although thymidine has been shown to supply the citrovorum factor for this organism, much larger quantities (10,000 times more than leucovorin) were required (*2*).

Wood and Hitchings (*3*) have shown recently that cell-free extracts of *P. cerevisiae* catalyze the transformation of pteroylglutamic acid into the citrovorum factor. They explained that the inefficiency of pteroylglutamic acid as a growth factor, in contrast to folinic acid, is due to its inability to permeate the cell membrane of *P. cerevisiae*.

We began to study the relationship of thymidine to folinic acid to elucidate the role of folic acid derivatives in the metabolism of *P. cerevisiae*. In the initial stage of this work we found that thymidine increased growth in the presence of folinic acid, but had no growth-promoting activity in its absence. The present report is confined to the elucidation of this interesting finding.

Figure 1 shows the effect of the addition of thymidine to graded amounts of folinic acid (*4*). At low concentrations of folinic acid (50 $\mu\mu$g/ml), the addition of thymidine caused a fourfold increase in growth, while at higher concentrations (200 $\mu\mu$g/ml) the increase was twofold; even at the highest concentration used (600 $\mu\mu$g/ml) the addition of thymidine resulted in a heavier growth than when folinic acid alone was added. The effective concentrations of thymidine were between 0.1 to 5 μg/ml. However, in the absence of folinic acid no visible growth was obtained even with concentrations of thymidine as high as 50 μg/ml.

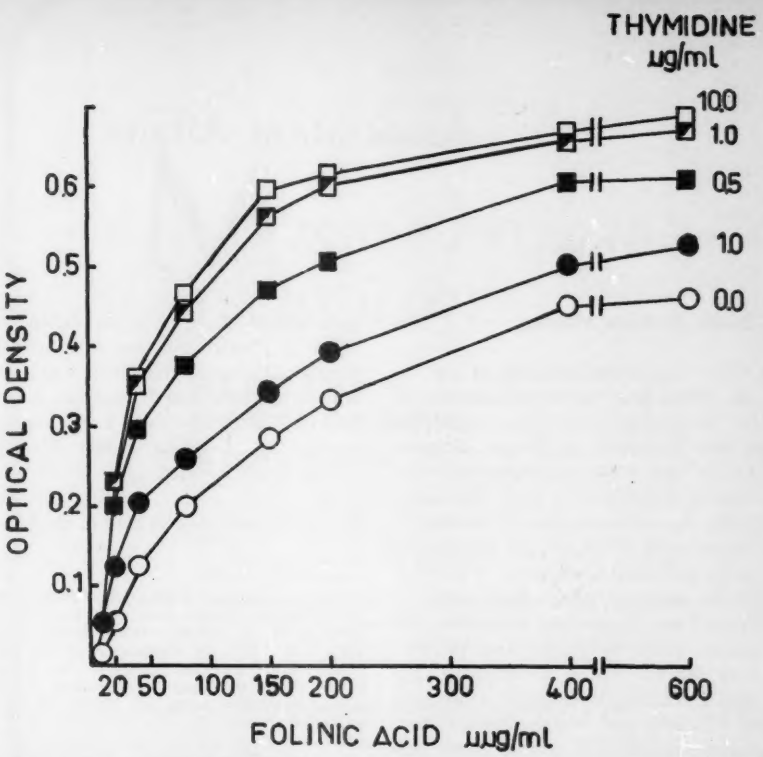


Fig. 1. Effect of thymidine on the growth response of *P. cerevisiae* (*L. citrovorum*) 8081 to graded amounts of folinic acid. Growth, expressed as optical density, was measured in the Coleman Junior spectrophotometer at 650 mμ after incubation for 48 hr at 37°C.

Thymidine was also found to increase the growth of *P. cerevisiae* in the presence of high concentrations of pteroylglutamic acid. In the presence of thymidine (1 μg/ml), visible growth occurred at an acid concentration of 0.2 μg/ml, whereas 10 times as much (2 μg/ml) was required to obtain similar growth in the absence of thymidine (*5*).

The medium was that of Toennies *et al.* (*6*), and the strain was obtained from the American Type Culture Collection.

The strain that shows the sparing effect of folinic acid by thymidine seems to be different from the original *P. cerevisiae* 8081 (*2*). Apparently, mutants of this organism are obtained rather easily. Nichol (*7*) selected strains that responded to lower concentrations of pteroylglutamic acid and which were found to display an increased sensitivity towards aminopterin.

The mechanism of the thymidine effect is not clearly understood at present. It would appear, however, that in this strain of *P. cerevisiae* folinic acid not only acts as a catalyst for the synthesis of thymidine but also for some other essential metabolite. Thus, the addition of thymidine spares folinic acid for its other functions.

NATHAN GROSSOWICZ
FREDERIKA MANDELBAUM
Department of Bacteriology, Hebrew University–Hadassah Medical School, Jerusalem, Israel

References and Notes

1. E. E. Snell, E. Kitay, W. McNutt, *J. Biol. Chem.* **175**, 473 (1948); H. E. Sauberlich and C. A. Baumann, *ibid.* **176**, 165 (1948).
2. H. E. Sauberlich and C. A. Baumann, *ibid.* **181**, 467 (1949); W. H. Prusoff, W. L. Holmes, A. D. Welch, *Cancer Research* **14**, 570 (1954).
3. R. C. Wood and G. H. Hitchings, *J. Bacteriol.* **79**, 524 (1960).
4. Leucovorin, Lederle Laboratories, Pearl River, N.Y.
5. Thymidine was obtained from two sources: California Corporation for Biochemical Research, Los Angeles, and Nutritional Biochemical Corporation, Cleveland, Ohio.
6. G. Toennies, H. G. Frank, D. C. Gallant, *Growth* **16**, 287 (1952).
7. C. A. Nichol, *Nature* **183**, 550 (1959).

24 March 1961

Association Affairs

Pacific Division Meeting

The 41st annual meeting of the Pacific Division, American Association for the Advancement of Science, was held at the University of Oregon, Eugene, 13–18 June 1960. Arrangements were capably handled by a local committee under the chairmanship of Bradley T. Scheer, head of the biology department.

The divisional symposium on 14 June, on the topic of "Man's Exploration of Space," was participated in by Manfred Eimer, chief, Research Analysis Section, Jet Propulsion Laboratory; Carl Sagan, Yerkes Observatory, University of Chicago; and Marsha Neugebauer, senior scientist, Division of Space Sciences, Jet Propulsion Laboratory. Seth Nicholson, director, Mount Wilson and Palomar Mountain Observatories, was the moderator. The symposium provoked animated questioning and discussion, which continued into the general reception immediately following.

The presidential address of Henry P. Hansen, president of the Pacific Division and dean of the Graduate School at Oregon State College, Corvallis, followed the divisional banquet on 15 June. Taking as his topic "Cycles and Geochronology," President Hansen presented the broader aspects of his own studies of fossil pollens, leading into such topics as climatic cycles, vulcanism, and early man in the Pacific Northwest.

Press coverage of the meeting was good, being interlocked with a special conference on science writing sponsored by the University of Oregon School of Journalism and the National Science Foundation, which brought to the meeting a number of nationally known science writers and provided a stimulating discussion of the special problems of science reporting.

Sixteen affiliated societies participated in the Eugene meeting with programs at which a total of 353 scientific papers were presented. The 857 registered members and guests were drawn from a wide geographical area, as shown in Table 1. Though this was a divisional meeting, 29 states, the District of Columbia, Canada, and 5 countries other than the United States and Canada were represented, with no region of the United States omitted.

The 42nd annual meeting of the Pacific Division will be held at the University of California at Davis, 19–24 June 1961. The president of the Division for 1961 is W. A. Clemens, professor of zoology emeritus, University of British Columbia. The president elect is Melvin Calvin, professor of chemistry, University of California at Berkeley. The chairman of the general committee for the Davis meeting is R. M. Hagan, professor of irrigation in the University of California at Davis.

R. C. MILLER
California Academy of Sciences, San Francisco

Table 1. Geographic distribution of registrants at the Eugene, Oregon, meeting of the Pacific Division of the AAAS. Italics indicate the eight states and the Canadian province of British Columbia that comprise the area of the Pacific Division. The combined registration from these areas was 754, or 88 percent of the total.

United States	
Alabama	1
Arizona	14
California	*320*
Colorado	21
Connecticut	1
District of Columbia	4
Florida	1
Georgia	1
Hawaii	*9*
Idaho	*15*
Illinois	7
Kentucky	1
Maryland	7
Massachusetts	3
Michigan	1
Minnesota	2
Montana	*5*
Nevada	*1*
New Mexico	2
New York	2
North Dakota	1
Ohio	2
Oregon	*223*
Rhode Island	1
Texas	7
Utah	*19*
Virginia	2
Washington	*141*
Wisconsin	2
Wyoming	4
Total	820
Other countries	
Canada:	
Alberta	4
British Columbia	*21*
Ontario	1
Saskatchewan	1
England	2
Honduras	1
India	5
Iraq	1
Thailand	1
Total	37

Lubrication Engineers

The lubrication engineer is associated with a great variety of operations. He is responsible for planned lubrication in virtually every industrial plant. In addition, he conducts research in lubricant development, bearing design and theory, and environmental analysis—activities which bring him into the related areas of physics, chemistry, and metallurgy.

In 1944 the increasing need for dissemination of information within this profession was recognized, and the American Society of Lubrication Engineers was founded. After 16 years of growth, the society (a recent affiliate of the AAAS) now has a membership of about 3000. More than 35 foreign countries, in both hemispheres, are represented in this number. Industry is considered a working partner in the structure of the society, and industrial membership is available to companies on a fee basis. At present there are 31 industrial members, including lubricant producers, lubricating equipment manufacturers, additive manufacturers, and others. Industry councils and technical committees, representing many branches of industry and research, report to a coordinator of councils and committees. Thus, education, research, and publications are coordinated in the many areas in which the lubrication engineer, by the nature of his profession, is active.

Programs of education in the fundamentals, practices, and theory of lubrication are held regularly, sponsored by local sections in cooperation with leading educational institutions. Other research and educational activities are undertaken by the society on a national basis.

The society publishes a monthly journal, *Lubrication Engineering*, and a semiannual publication, *ASLE Transactions*. *Lubrication Engineering* con-

tains technical papers in the field of lubrication, information on lubricants and lubrication devices, news of the various sections of the society; news of product and plant applications; news of developments in the field of lubricant testing; and examples of the benefits of a planned lubrication program. *ASLE Transactions* is devoted to papers of a more theoretical nature. The society issues handbooks on fundamentals and research problems, full-scale volumes treating of important and relatively neglected areas of research, and noteworthy texts not otherwise available in this country.

The society holds two regularly scheduled meetings each year—the ASLE Annual Meeting and Lubrication Exhibit, held in the spring, and the Joint Lubrication Conference, held in the fall and cosponsored by other engineering groups.

Current officers of the society are as follows: president, L. O. Witzenburg (Eaton Manufacturing Company); secretary, A. E. Cichelli (Bethlehem Steel Company); treasurer, W. E. Hoch (Viscosity Oil Company); vice-president at large, D. M. Cleaveland (Bendix Corporation); and executive secretary, Calvert L. Willey.

CALVERT L. WILLEY
American Society of Lubrication Engineers, Chicago, Illinois

Science Abstracting and Indexing

The National Federation of Science Abstracting and Indexing Services, a new affiliate of the AAAS, was organized in 1958 by the major abstracting and indexing organizations of the United States to coordinate their efforts and seek ways of improving them. The ultimate goal of the federation is to improve communication among scientists through the documentation (abstracting, indexing, and analyzing) of international scientific literature.

The federation provides a broad and comprehensive program. Its activities range from research and education to the publication of lists of scientific and technological periodicals. As new problems or new techniques arise from advances in documentation, the federation will broaden its activities by including them.

By means of working group committees reporting to the secretariat, the federation is endeavoring to achieve its aims through cooperative efforts in such

ENGINEERS
MATHEMATICIANS
PHYSICISTS

MISSILE PAYLOAD TECHNOLOGY

RESEARCH
DEVELOPMENT
ANALYSIS

The Applied Physics Laboratory of The Johns Hopkins University has prime responsibility for the development of guided missile weapon systems for the U. S. Navy. One technical group within APL is specifically concerned with the research, development and analysis of warheads for these missiles which include TERRIER, TALOS, TARTAR and TYPHON. For purposes of description, the activities of this group may be divided as follows:

SUPPORTING—APPLIED RESEARCH: Supporting and applied research pertaining to warhead technology and explosive phenomena are conducted, including theoretical analysis, laboratory and field test experimentation.

DESIGN AND DEVELOPMENT: Group efforts are concerned with the research, design, direction of fabrication, development and actual testing of prototype devices. Also included is the data reduction, processing, and analysis of test results.

ANALYTICAL: The Warheads Group also performs design analyses for determination of most suitable warhead types depending on specific weapon system and target performance characteristics. Warheads under development are critically evaluated in terms of test objectives and ultimate weapon system acceptance by the Navy. Lethality analyses, mathematically simulating missile-target spatial intercept geometries also are conducted in conjunction with specific warhead research and development. For this purpose, an IBM 7090 is available to the group at APL's Computing Center.

The several assignments open at this time are exceedingly diversified and challenging. New staff members will have the opportunity to extend their professional capabilities both in the field of warheads and such associated fields as fuzing, guidance, missile structures and operational analysis. Technical liaison with other APL groups, subcontractors, and government agencies provides a wide range of activities in support of the primary mission of the Warheads Group. Initial and future assignments will be made in accordance with background qualifications of applicants, their interests, and the needs of the technical program.

You will find an intellectual and professionally stimulating environment at APL, and the opportunities for significant contributions and personal advancement are excellent. You will be associated with colleagues in numerous disciplines and technical specialties, many of whom have earned reputations as leaders in their fields. Your work will enhance our national purpose, since it has a material bearing on the defense capability of our country.

Scientists and engineers, both on senior and intermediate levels, are invited to direct their inquiries to:

Professional Staff Appointments

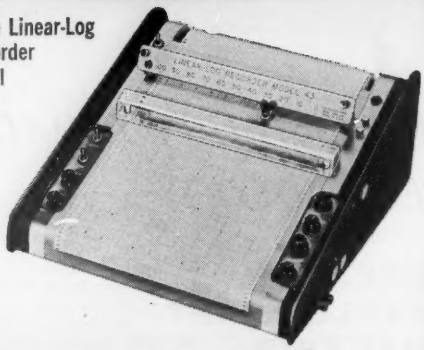
The Applied Physics Laboratory · The Johns Hopkins University

8615 Georgia Avenue, Silver Spring, Maryland
(A residential suburb of Washington, D.C.)

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

LINEAR/LOG RECORDER

A versatile Linear-Log Servo-Recorder for general laboratory use



VARICORD 43 $725

- Multi-range, potential and current recorder.
- Choice of per cent transmission or absorbance indication in spectrophotometry.
- For gas chromatography by conductivity or ionization.
- True potentiometric input.
- 1 second pen speed—10 millivolt full scale sensitivity.
- Output connector for integrating and telemetering.

Write for Bulletin #7130

PHOTOVOLT CORP.

1115 BROADWAY • NEW YORK 10, N.Y.

Also available: Densitometers ■ Photometers ■ Fluorescence Meters ■ pH Meters

NO lost experiments with MICROSCOPIC SLIDE LABELING

Eliminate guesswork . . . greasemark mistakes. Get positive identification. Simply pull tab and a fresh, clean label "pops" out. Fast, self-sticking labels dispensed one at a time. Available in standard or "tissue-high" thickness. They accept pen, pencil, ball point pen or typewriter marking. 1000 labels per carton.

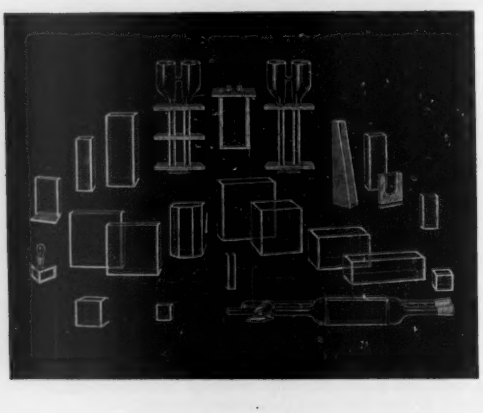
TIME SELF-STICKING LABELS VINYL COATED

Write for detailed information and the name of your nearest TIME distributor.

PROFESSIONAL TAPE CO., INC.

360 Burlington Ave. • Riverside, Ill.

GLASS ABSORPTION CELLS made by KLETT

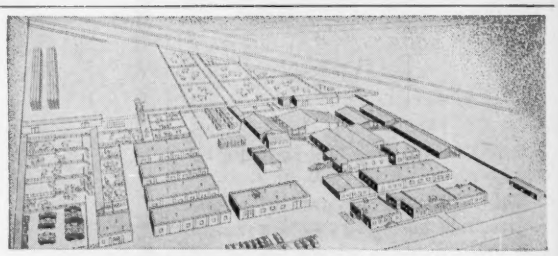


SCIENTIFIC APPARATUS

Klett-Summerson Photoelectric Colorimeters—Colorimeters — Nephelometers — Fluorimeters—Bio-Colorimeters — Comparators — Glass Standards—Klett Reagents.

Klett Manufacturing Co.

179 East 87 Street, New York, New York



Production experience guarantees

RELIABILITY

Order with confidence, the quality and dependability your laboratory and research needs demand. Prompt service. All correspondence and inquiries answered immediately.

- serums • bloods
- ultrafiltrates
- complement • globulins
- fluorescent materials
- diagnostic reagents
- tissue culture reagents

We maintain a variety of our own laboratory animals under the finest conditions.

Write for this FREE CATALOG NOW! *No salesman will call.*

COLORADO SERUM CO.

LABORATORIES

Laboratory and General Office PEAK OF QUALITY

4950 YORK STREET • DENVER 16, COLORADO • MAin 3-5373

problem areas as bibliographic, indexing; and abstracting standards; coverage overlaps and gaps; transliteration; copyright laws; definition of terminology; costs and financing; procurement of hard-to-obtain journals; journal inventories; mechanization in all phases of the operation of secondary-source information services; and information retrieval. For example, the federation has recently adopted a uniform standard for Cyrillic transliteration.

The affairs of the federation are administered by the executive secretary and his staff in the national offices, located at 301 East Capitol Street, Washington, D.C.

Members of the federation include the following: *Applied Mechanics Reviews, ASTIA Technical Abstract Bulletin, Bibliography of Agriculture, Biological Abstracts, Chemical Abstracts, Engineering Index, Fire Research Abstracts and Reviews, GeoScience Abstracts, Index Medicus, International Aerospace Abstracts, Mathematical Reviews, Meteorological and Geoastrophysical Abstracts, Nuclear Science Abstracts, Prevention of Deterioration Abstracts, Psychological Abstracts, Review of Metal Literature, Tobacco Abstracts,* and *United States Government Research Reports* (Office of Technical Services, U.S. Department of Commerce).

The federation holds annual meetings, the most recent of which was held in Cleveland on 9 and 10 March. Papers were presented as follows: "The literature problem for scientists and engineers," Richard S. Leghorn (president, Itek Corporation); "The price tag for meeting the literature crises," G. Miles Conrad (director, *Biological Abstracts*); and "The impact of the information problem upon higher education," John S. Millis (president, Western Reserve University). A panel discussion on responsibilities for meeting the literature crisis was moderated by Allen Kent (Center for Documentation and Communication Research, Western Reserve University); participants were Dolph G. Ebeling (Knolls Atomic Power Laboratory, General Electric Company, Schenectady, N.Y.), Burton W. Adkinson (Office of Science Information Service, National Science Foundation), Edwin Castagna (Enoch Pratt Free Library), Jesse H. Shera (School of Library Science, Western Reserve University), and Verner W. Clapp (Council on Library Resources, Inc.).

Officers of the federation for 1961–62 are as follows: Dale B. Baker (Chemical Abstracts Service), president; John C. Green (Office of Technical Services, U.S. Department of Commerce), vice-president; Marjorie R. Hyslop (*Review of Metal Literature*), treasurer; Carolyn M. Flanagan (*Engineering Index*), secretary. Other members of the board of directors are Robert L. Shannon (Office of Technical Information Extension, U.S. Atomic Energy Commission); Arthur C. Hoffman (*Psychological Abstracts*); Martin Goland (*Applied Mechanics Reviews*); S. H. Gould (*Mathematical Reviews*); J. Heston Heald (*ASTIA Technical Abstract Bulletin*); Margaret S. Bryant (U.S. Department of Agriculture Library); Seymour I. Taine (National Library of Medicine); G. Miles Conrad (*Biological Abstracts*); and Kenneth C. Spengler (*Meteorological and Geoastrophysical Abstracts*).

Federation publications include *A Guide to U.S. Indexing and Abstracting Services in Science and Technology* (prepared by the Library of Congress); *Some Counterparts in Perspective (A detailed report on visits to the Soviet All-Union Institute of Scientific and Technical Information; the Polish Central Institute for Documentation in Sci-*

. . . in response to inquiries for a simple, basic syringe driver directly aimed towards applications that require operation at one delivery rate, while providing a wide range of choice of this rate.

This basic apparatus consists of a synchronous motor drive and a syringe holder. Drive is arranged to accept any one of fifty interchangeable ratio gears and syringe holders are available for 50, 30, 20, 10, 5, 2, 1, and .5 ml capacities. The above gears provide for rotation of the syringe holder driving screw throughout a range of one revolution in ten minutes to one revolution in three hours.

Pump is a single stroke unit and is normally furnished with the ratio gears that provide a single, selected delivery rate with any given syringe. The wide choice of ratio gears and syringe capacities provide a practically unlimited choice of delivery rates up to the maximum of 2.35 ml per hour. With synchronous motor drive, delivery rate is constant and predictable. 115 volt, 60 cycle, a.c. lines.

Catalog No. 71-045

PHIPPS & BIRD, INC.
Manufacturers & Distributors of Scientific Equipment
6th & Byrd Streets - Richmond, Va.

PROPIPETTE

Safety Pipette Filler
holds liquids indefinitely

• Time Tested • No moving parts
• Simple to operate

The new PROPIPETTE eliminates the dangerous practice of using the mouth to draw liquids into pipettes. It is simple to use and the operator soon becomes proficient so that liquids can be delivered quickly, precisely and safely. Measurement precision is extremely high (0.01cc). The instrument has three agate-ball valves which operate independently and the entire procedure can be done with only one hand.

PRICE $6.90 each . . . comes in black, red, green and blue, sent on approval.

all laboratory pipettes can be used with the PROPIPETTE—Safety Pipette Filler.

Write for additional information

INSTRUMENTATION ASSOCIATES
Distributors of Laboratory and Scientific Specialties

17 West 60th Street New York 23, N.Y.

THE HUMAN INTEGUMENT
NORMAL AND ABNORMAL

Editor: Stephen Rothman 1959

AAAS Symposium Volume No. 54

A symposium presented on 28-29 December 1957, at the Indianapolis meeting of the American Association for the Advancement of Science and cosponsored by the Committee on Cosmetics of the American Medical Association and the Society for Investigative Dermatology. The volume offers a fair illustration of what has been achieved by modern research in cultaneous physiology and pathophysiology.

270 pp., 59 illus., index, cloth. $6.75
AAAS members' cash orders $5.75

Chapters

1) The Integument as an Organ of Protection
2) Circulation and Vascular Reaction
3) Sebaceous Gland Secretion
4) Pathogenetic Factors in Pre-malignant Conditions and Malignancies of the Skin

British Agents: Bailey Bros. & Swinfen, Ltd., Hyde House, W. Central Street, London, W.C.1

AAAS

1515 Massachusetts Ave., NW
Washington 5, D.C.

ence and Technology; the Excerpta Medica Foundation and the Danish Technical Information Service), by D. B. Baker, G. M. Conrad, J. C. Green, M. Hoseh, and R. A. Jensen; and the published proceedings of each year's annual meeting.

The federation has recently undertaken the preparation of a program for studying the role of science abstracting and indexing services in solving the over-all information problem. The results of this work should provide a broad picture of efforts to communicate scientific information in the United States, from the time such information is available until it becomes obsolete. It is hoped that this plan will provide direction for all efforts in abstracting and indexing in the United States, both within and outside the government, for some years ahead.

The present AAAS Council representative is G. Miles Conrad, organizer, founder, and first president of the federation.

RAYMOND A. JENSEN
National Federation of Science Abstracting and Indexing Services, Washington, D.C.

Forthcoming Events

June

22–23. American Rheumatism Assoc., New York, N.Y. (F. E. Demartini, 622 W. 168 St., New York 32)

22–23. Computers and Data Processing, 8th annual symp., Estes Park, Colo. (W. H. Eichelberger, Denver Research Inst., Univ. of Denver, Denver, Colo.)

22–24. Endocrine Soc., New York, N.Y. (H. H. Turner, 1200 N. Walker, Oklahoma City 3, Okla.)

22–26. American College of Chest Physicians, New York, N.Y. (M. Kornfeld, 112 E. Chestnut St., Chicago 11, Ill.)

23–25. American College of Angiology, 7th annual, New York, N.Y. (A. Halpern, Secretary, 11 Hampton Court, Great Neck, N.Y.)

25–28. American Soc. of Agricultural Engineers, annual, Ames, Iowa. (J. L. Butt, 420 Main St., St. Joseph, Mich.)

25–29. Morphological Precursors of Cancer, intern. symp. (by invitation only), Perugia, Italy. (L. Severi, Div. of Cancer Research, Univ. of Perugia, P.O. Box 167, Perugia)

25–30. American Medical Assoc., 110th annual, New York, N.Y. (AMA, 535 N. Dearborn St., Chicago 10, Ill.)

25–30. American Soc. for Testing Materials, Atlantic City, N.J. (R. J. Painter, 1916 Race St., Philadelphia, Pa.)

25–30. International Union of Leather Chemists Societies, 8th congr., Washington, D.C. (F. O'Flaherty, Dept. of Leather Research, Univ. of Cincinnati, Cincinnati 21, Ohio)

25–30. National Education Assoc. of the U.S., Atlantic City, N.J. (W. G. Carr, 1201 16 St., NW, Washington 6)

26–27. Conference on Vacuum Metallurgy, 5th annual conf., New York, N.Y. (R. F. Bunshah, Dept. of Metallurgical Engineering, New York Univ., New York 53)

26–28. American Soc. of Heating, Refrigerating and Air-Conditioning Engineers, 68th annual, Denver, Colo. (J. H. Cansdale, ASHRAE, 234 Fifth Ave., New York 1)

26–28. Control of Noise, symp., Teddington, England. (Director, Natl. Physical Laboratory, Teddington, Middlesex)

26–28. European Symp. on Space Technology, London, England. (Secretary, British Interplanetary Soc., 12 Bessborough Gardens, London, S.W.1)

26–28. Military Electronics, 5th natl. convention, Washington, D.C. (H. Davis, SAFRD, Pentagon, Washington 25)

26–30. American Soc. for Engineering Education, annual, Lexington, Ky. (M. Baker, Univ. of Kentucky, Lexington)

26–30. Concepts and Design in Aerospace Electricity, Philadelphia, Pa. (D. H. Scott, General Electric Co., No. 3, Penn Center Plaza, Philadelphia 2)

26–30. Reading Conf., 3rd annual, Syracuse, N.Y. (R. A. Kress, Syracuse Univ., Syracuse 10)

26–9. Large Dams, 7th intern. congr., Rome, Italy. (U.S. Committee on Large Dams, c/o Engineering Joint Council, 29 W. 39 St., New York 18)

27. Colloid Symp., by Faraday Soc., Glasgow, Scotland. (A. S. Hyde, Chemistry Dept., Royal College of Science and Technology, Glasgow, C.1)

27–29 Analytical Astrodynamics, intern. symp., Santa Barbara, Calif. (Capt. J. L. Gilbert, Air Force Office of Scientific Research, Washington 25)

27–29. Society for Investigative Dermatology, Inc., New York, N.Y. (H. Beerman, 255 S. 17 St., Philadelphia 3, Pa.)

27–30. American Home Economics Assoc., Cleveland, Ohio. (Miss M. Warren, School of Home Economics, Univ. of Oklahoma, Norman)

27–30. Hurricanes, 2nd technical conf., American Meteorological Soc., Miami Beach, Fla. (AMS, 45 Beacon St., Boston 8, Mass.)

28–30. International Gas Conf., 8th, Stockholm, Sweden. (R. H. Touwaide, Union Internationale de l'Industrie du Gaz, 4, avenue Palmerston, Brussels 4)

28–30. Joint Automatic Control Conf., Boulder, Colo. (R. Kramer, Massachusetts Inst. of Technology, Cambridge 39)

28–1. Institute of Navigation, annual, Williamsburg, Va. (C. T. French, General Precision, Inc., 777 14 St., NW, Suite 611, Washington, D.C.)

29–1. American Assoc. of Physics Teachers, Stanford, Calif. (R. P. Winch, Williams College, Williamstown, Mass.)

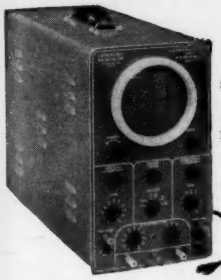
July

1–3. Astronomical League, Detroit, Mich. (W. A. Cherup, 4 Klopfer St., Millvale, Pittsburgh 9, Pa.)

(See issue of 19 May for comprehensive list)

New Welch Cathode-Ray Oscilloscope

Possesses All the Features Essential for Tests and Demonstrations Extensively Field Proven in Classroom and Laboratory



5-inch screen

CONDENSED SPECIFICATIONS

Sensitivity, Vertical and Horizontal Axes:
Direct ----------15 rms volts/inch
Full Gain ----------0.5 rms volts/inch

Input Impedance, Vertical and Horizontal Axes:
Direct ----------3 meg
Amplifier ----------0.5 meg., 20 mmf

Sweep Frequency Range ---10 cps to 60 kc

Operating Voltage, 105-120 volts, 50/60 cycle A.C.
Dimensions ------8½x14½x18½ inches
Shipping Weight----------42 pounds

2167. CATHODE-RAY OSCILLOSCOPE. This is a general-purpose instrument intended for routine laboratory tests and class room demonstrations. Extensive field testing has proved it to be well suited to the requirements of colleges, technical schools, and high schools. Students will quickly understand the function of all the controls, and the high-grade components and careful workmanship assure long reliable service.

The 5-inch cathode-ray tube employs electrostatic deflection and focus, and is operated at an accelerating potential of about 1200 volts. Post-deflection acceleration increases its brillance and sensitivity.

Instructions are included. **Each $158.50**

THE WELCH SCIENTIFIC COMPANY

ESTABLISHED 1880

1515 Sedgwick Street, Dept. E, Chicago 10, Illinois, U.S.A.

Manufacturers of Scientific Instruments and Laboratory Apparatus

new england nuclear

Cholic-carboxyl-C^{14}-Acid

$180 per 100 uc
$100 per 50 uc

CATALOG ON REQUEST

new england nuclear corp.

575 ALBANY STREET, BOSTON 18, MASS. Liberty 2-5964

PERSONNEL PLACEMENT

CLASSIFIED: Positions Wanted 25¢ per word, minimum charge $4. Use of Box Number counts as 10 additional words. Payment in advance is required.

COPY for ads must reach SCIENCE 2 weeks before date of issue (Friday of every week).

DISPLAY: Positions Open. Rates listed below—no charge for Box Number. Rates net. No agency commission. No cash discount. Minimum ad: 1 inch. Ads over 1 inch will be billed to the nearest quarter inch. Frequency rate will apply to only repeat of same ad. No copy changes. Payment in advance is required except where satisfactory credit has been established.

Single insertion	$40.00 per inch
4 times in 1 year	38.00 per inch

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

Replies to blind ads should be addressed as follows:
Box (give number)
Science
1515 Massachusetts Ave., NW
Washington 5, D.C.

POSITIONS WANTED

Biochemist. Academic appointment. Research and teaching. Graduate faculty. Publications. Dr. J. H. Schneider, American University, Beirut, Lebanon. 4/28; 5/12, 26; 6/9

Chemist. M.S. Physical-Biochemical, 5 years' experience teaching; protein analysis, separation and structure; immunochemistry. Box 111, SCIENCE. 6/2

Gastroenterologist. Certified in both internal medicine and in gastroenterology. Mayo Clinic and university training. Desires change of location. Box 108, SCIENCE. 5/19; 26

POSITIONS WANTED

Organic Chemist. Ph.D. Age 43. Fourteen years' experience in the pharmaceutical industry. Now group leader. Desires challenging position—industrial or academic. Box 112, SCIENCE. X

POSITIONS OPEN

BIOCHEMIST

Ph.D., with experience in enzyme work, to be jointly appointed by the University of Buffalo and Roswell Park Memorial Institute. Write to Dr. T. J. Bardos, School of Pharmacy

University of Buffalo
Buffalo 14, N.Y.

RESEARCH ASSISTANTS

An expanding midwestern pharmaceutical company has opportunities for research assistants in pharmacology research unit. Medical technology or bachelor of science level preferred. Positions involve application of enzymology, physiology, analytical chemistry, and isotope techniques to a study of drug action. Previous association, either academic or practical, with methodology in some or all of these areas is desired. Please send complete résumé to:

Technical Employment Coordinator
UPJOHN COMPANY
Kalamazoo, Michigan

POSITIONS OPEN

ZOOLOGIST

Vertebrate zoology; physiology. Northeast. Man or woman Ph.D. Private college of 900 affiliated with large university. Desire to continue own research interests important.

BOX 114, SCIENCE

BIOLOGICAL SCIENTIST—Ph.D.

Outstanding opportunity in research division of major Philadelphia pharmaceutical firm for Ph.D. in physiology or biochemistry. Important role in research and development of new therapeutic agents including design of laboratory and clinical studies; interpretation of data and evaluation of clinical utility. Candidate should have good academic qualifications; ability and interest in working with both scientists and management; facility in oral and written communication. Opportunity to attend appropriate scientific meetings and to make outside contacts with other scientists and clinicians. Send complete résumé including salary requirements to:

W. R. HALL

Smith Kline & French Laboratories

1598 Spring Garden Street, Philadelphia 1, Pa.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

POSITIONS OPEN

ORGANIC BIOCHEMIST

For electrophoretic and chromatographic study of gastrointestinal mucoproteins and polysaccharides in basic science research laboratory. Ph.D. Send professional record, references, salary requirements to:

BOX 116, SCIENCE

PHYSIOLOGIST—Ph.D. or M.D.

Research on ion transport processes in digestive secretions. Research Laboratory for Gastrointestinal Physiology. Metropolitan N.Y. Send professional record, references, salary requirements to:

BOX 115, SCIENCE

WANTED: CO-EDS AND GRADUATES INTERESTED IN THE MEDICAL FIELD

Women college graduates with science backgrounds (single 21-29) are eligible to apply for an excellent 12-month course in Physical Therapy. Selected candidates will earn full salary while learning—with all school and travel expenses paid. This course—sponsored by the Army Medical Service—is approved by the Council on Medical Education and Hospitals, American Medical Association.

Upon acceptance, students are commissioned 2nd Lieutenants in the Army Medical Specialist Corps (AMSC) Reserve, and are required to serve one year on active duty after completion of the 12-month course. (Monthly salary begins at $270.00 plus substantial fringe benefits.) AMSC officers receive 30 days of paid vacation every year—and enjoy career opportunities for advanced professional training and world travel.

For complete information, write:

THE SURGEON GENERAL
Department of the Army
Washington 25, D. C.

OPTICAL & INFRARED PHYSICISTS & ENGINEERS

Melpar's Expanding Research Activities Offer Exciting Opportunities For The Research Scientists With New and Novel Approaches To Problems Involving

OPTICAL & INFRARED SYSTEM DESIGN

Present Areas of Investigation Are In:

- **BIOPHYSICAL INVESTIGATIONS RELATED TO INFRARED SENSING**
- **PROPERITIES OF THE ATMOSPHERE, INCLUDING VERY LONG WAVELENGTH INVESTIGATIONS, SCINTILLATION AND ABSORBTION STUDIES**
- **OPTICAL HETRODYNE STUDIES AND TUNABLE IRASERS**
- **APPLICATIONS OF EXTREMELY HIGH ELECTROMAGNETIC FIELDS**

The experienced investigator will find at Melpar a research oriented environment with all the necessary experimental facilities. And he will be associated with a research group of nationally recognized stature.

Send Resume
In Complete Confidence To

MELPAR, INC.

300 Arlington Boulevard,
Falls Church, Virginia
Attention Mr. F. J. Drummond

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

POSITIONS OPEN

CLINICAL BIOCHEMIST

Master's or Ph.D. degree preferred. Responsible directly to M.D., Director of Clinical Laboratories. Salary range $7000–$10,000 annually, experience given additional consideration; 500-bed, short-term general hospital in northeastern Ohio. Contact Director of Clinical Laboratories

Aultman Hospital
Canton 10, Ohio

SCIENCE TEACHERS

Long Island School District, Western Suffolk area, seeks two senior high science teachers; one with strength in physics and chemistry; one with strength in biology and chemistry. Should be willing to work with youth while maintaining a lively interest in science. Must have M.A. in science and have or be willing to take basic requirements for N.Y.S. teaching certificate. Entering salary range $5600–$8900. Prefer teaching experience. Résumé.

BOX 113, SCIENCE

VIROLOGIST

To plan and conduct investigational, diagnostic, base-line, and surveillance studies of viruses and related organisms in the Hawaii state public health laboratory. Requires 2 years' experience in propagating, detecting, and identifying viruses and completion of graduate work leading to a Ph.D. in virology, bacteriology, or a related field. Salary $8256–$10,536 per annum. Write to Department of Personnel Services, 825 Mililani Street, Honolulu 13, Hawaii.

The Market Place

BOOKS • SERVICES • SUPPLIES • EQUIPMENT

DISPLAY: Insertions must be at least 1 inch in depth. Weekly invoices will be sent on a charge account basis—provided that satisfactory credit is established.

Single insertion	$48.00 per inch
4 times in 1 year	44.00 per inch
13 times in 1 year	42.00 per inch
26 times in 1 year	40.00 per inch

PROOFS: If copy is to be set, and proofs submitted for approval, complete copy and cuts must be received 4 weeks in advance of publication date (Friday of each week); complete plates no later than 3 weeks in advance of publication date.

SUPPLIES AND EQUIPMENT

"From the hand of the veterinarian to research"®

albino rats

CHARLES RIVER *CD
(Caesarean derived)
CHARLES RIVER SD
(Sprague-Dawley descendants)
CHARLES RIVER W
(Wistar descendants)

HYPOPHYSECTOMIZED RATS

- Only Charles River CD animals used
- Rigidly controlled environment (same bldg.) birth to surgery.
- High speed surgery by graduate biologists.
- 10 years experience animal surgery.
- Overnight air service from Boston

® Trademark

THE CHARLES RIVER BREEDING LABS
1018 Beacon St., Brookline 46, Mass. RE. 4-2000
Henry L. Foster, D.V.M., President

SUPPLIES AND EQUIPMENT

YOU NEED THIS FREE CATALOG FOR YOUR FILES

Serums, antiserums and bloods of all kinds for technicians and tissue culture laboratories. No salesman will call.

COLORADO SERUM CO.
4950 York St. • MAin 3-5373 • Denver 16, Colo.

CHARLES RIVER *CD-1
(Caesarean-derived)

HIGH ® ALBINO **Mice** SWISS ICR STRESS

Hypophysectomies available

* Trademark

THE CHARLES RIVER MOUSE FARMS
1018 Beacon St., Brookline 46, Mass., RE 4-2000

PROFESSIONAL SERVICES

CONSULTATION AND RESEARCH SINCE 1922

Food and Drug Research Laboratories INCORPORATED

Toxicology • Pharmacology
Nutrition • Biochemistry • Bacteriology

BERNARD L. OSER, Ph.D., Director

Maurice Avenue at 59th Street
Maspeth 78, New York City

TWining 4-0600

WHERE EXPERIENCE COUNTS

BOOKS AND MAGAZINES

SCIENTIFIC JOURNALS WANTED

Sets, Runs and Volumes bought at top prices. Your wants supplied from our Back Files of over 3,000,000 periodicals. **Abrahams Magazine Service N. Y. 3, N. Y.**

Your sets and files of scientific journals

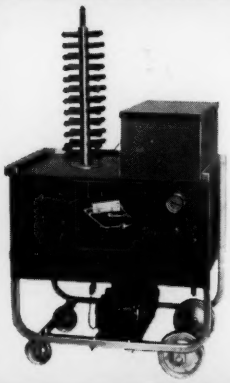
are needed by our library and institutional customers. Please send us lists and description of periodical files you are willing to sell at high market prices. Write Dept. A3S, CANNER'S, Inc. Boston 20, Massachusetts

Proceedings of a conference by
NAS–NRC Committee on Photobiology

PHOTOPERIODISM
AND RELATED PHENOMENA
IN PLANTS AND ANIMALS

922 pp., 256 illus., 1959 $14.75
$12.50 cash orders from AAAS members

AAAS
1515 Massachusetts Ave., NW
Washington 5, D.C.



MULTI-CENTRIFUGAL MOBILE

Fully-equipped mobile unit automatically forms perfect shells in glass containers by centrifugal action. Eliminates slow and tedious old-fashioned shell freezing methods; drying time is cut by at least 20%. Stainless-steel condensor has a 10-liter capacity; works off a Cenco vacuum Hyvac pump. Belt-driven, adjustable-speed centrifuge has 14 revolving platforms in stainless-steel housing that incorporates a 1" lucite top with gasket for top loading operation. Stainless-steel manifold has 50 ports. Includes glass McLeod gauge, control panel, timer. *Model CFD-1* (Cenco Hyvac 2-pump, 20 liters/min., 0.1 micron); *Model CFD-2* (Same as above but with two multi-centrifuge boxes for alternate or simultaneous operation).

FREEZE DRYERS

&

ASSOCIATED EQUIPMENT

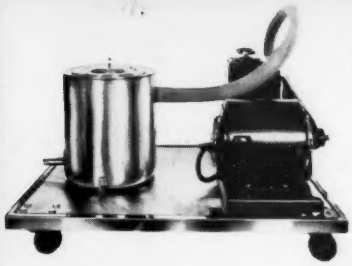
TABLE MODELS & ACCESSORIES

All equipment is so designed that it can be associated with refrigerating and vacuum apparatus to perform a number of functions. The following accessories may be combined with the *VacTrap* or *Circu-Freeze*.

FREEZE DRYERS: Stainless-steel freeze dryers with 6-18 ports and two for connections to vacuum gauge and pump. Ports available in either ½" or ¾" OD. Capacity, center well, 225cc to 7 liters of dry ice and acetone. Arc welded construction.

MANIFOLD: Stainless steel unit with 50 ports in ½" or ¾" OD. Available for vertical or horizontal mounting.

TRAPS: Stainless-steel traps available with ½" or ¾" OD ports. Dry ice and acetone volume from 1.5 to 3.0 liters.



VACTRAP

PORTABLE CONDENSING SYSTEM PLACES THE STAINLESS STEEL VACUUM TRAP AND VACUUM PUMP BELOW THE LABORATORY BENCH TO SAVE VALUABLE WORKING SPACE; UNIT IS MOUNTED ON A STAINLESS STEEL DOLLY FOR MOBILITY.

FEATURES: Cenco Hyvac pump, 10 liters/minute capacity, with ultimate vacuum at .3 microns; stainless steel heavy-duty condensor with two ½" ports; non-slip pure gum gasket; rapid vacuum break device; pure gum heavy wall stock rubber tubing. Pumps and traps are available in varying sizes and capacities.

CIRCU-FREEZE

EXTREMELY VERSATILE PORTABLE UNIT FOR LOW TEMPERATURE −60°F DRY AIR STORAGE, OR −30°F CIRCULATING BRINE CHILLING UNIT.

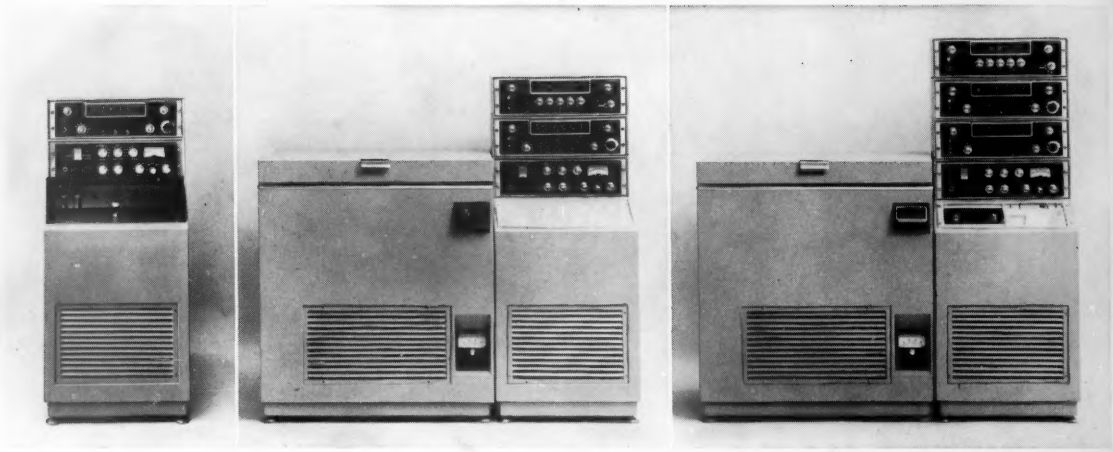
Constructed of heavy-duty stainless steel; measures 22" x 14" x 25". Stainless-steel drum, 8" x 8¾" has total capacity of 6 quarts; other drum capacities are available to fit specific needs. Includes: inlet and outlet fixtures, electrical connections and switchgear. All units are mounted on rigid frame with 4 rubber casters for mobility. Also available in lower temperature ranges.

- VERSATILE
- CUSTOMIZED
- RUGGED CONSTRUCTION
- ADVANCED ENGINEERING
- BUDGET PRICED

INSTRUMENTATION ASSOCIATES, INC.

Laboratory and Scientific Specialties

17 West 60th Street New York 23, N. Y.



1.
Start here for economical, room-temperature counting of C^{14} and H^3
Model 701
manual operation, shown with 8250 scaler

2.
Add cooling for increased efficiency and precision
Model 702
manual, temperature controlled operation, shown with 8250 scaler and 8600 timer

3.
Incorporate automatic sample changing as work load grows
Model 703
automatic, temperature controlled operation, shown with two 8250 scalers, 8600 timer, and 8401 digital recorder

New from Nuclear-Chicago... a family of liquid scintillation counting systems

Model 701 is the low-priced basic system for workers interested mainly in counting limited numbers of samples. Carbon-14 is counted with high efficiency and tritium with somewhat reduced efficiency. Model 701 includes components common to all three systems: uniquely sensitive optical cell and dual-detector assembly, high-speed two-channel pulse-height analyzer, ultra-fast coincidence circuit, and stabilized high-voltage supply. Output signals from this solid-state circuitry are shaped pulses which can feed any standard scaling instrument. From this point, your research needs and budget will guide your choice of options, now and in the future.

In Model 702, the dual-detector assembly is mounted in a custom-built, precision-controlled, low-temperature chamber permitting highest counting efficiency for carbon-14 and tritium. Field conversion to fully automatic operation requires only addition of the sample changer mechanism.

Model 703's simple and foolproof sample changer, its sophisticated options of data presentation, and its versatile modes of automatic operation suggest it as the system of choice for laboratories counting many samples.

One of the three new models in this first family of liquid scintillation counting systems is suited to your present research needs and to your expanding programs of investigation.

Prices for these integrated, compact and functionally elegant systems range from $5,000 through $15,000. Please write for full information.

nuclear-chicago
CORPORATION

349 EAST HOWARD AVENUE, DES PLAINES, ILLINOIS